2018

Investigation of Factors Contributing to Fog-Related Single Vehicle Crashes

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INVESTIGATION OF FACTORS CONTRIBUTING TO FOG-RELATED SINGLE VEHICLE CRASHES

by

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A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Civil, Environmental and Construction Engineering
in the College of Engineering and Computer Science
at University of Central Florida
Orlando, Florida

Spring Term
2018

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ABSTRACT

Fog-related crashes continue to be one of the most serious traffic safety problems in Florida. Based on the historical crash data, we found that single-vehicle crashes have the highest severity among all types of crashes under fog conditions. This study first analyzed the contributing factors of the fog-related single-vehicle crashes' (i.e., off road/rollover/other) severity in Florida from 2011 to 2014 using association rules mining. The results show that lane departure distracted driving, wet road surface, and dark without road light are the main contributing factors to severe fog-related single vehicle crashes. Some suggested countermeasures were also provided to reduce the risk of fog-related single vehicle crashes. Since lane departure is one of the most important contributing factors to the single-vehicle crashes, an advanced warning system for lane departure under connected vehicle system was tested in driving simulation experiments. The system was designed based on the Vehicle-to-Infrastructure (V2I) with the concept of Augmented Reality (AR) using Head-Up Display (HUD). The results show that the warning with sound would reduce the lane departure and speed at curves, which would enhance the safety under fog conditions. In addition, the warning system was more effective for female drivers.

Keywords: traffic safety; fog; countermeasure; association rules; Vehicle-to-Infrastructure; Head-Up Display

ACKNOWLEDGMENT

The author would like to thank his advisor, Dr. Mohamed Abdel-Aty, for his invaluable guidance, advice and support. The author would like to acknowledge the support of his committee members, Dr. Samiul Hasan and Dr. Yina Wu. The author would like also to acknowledge the financial and data support from the Florida Department of Transportation (FDOT) and SAFER-SIM. The opinions expressed in this thesis are the author's own and do not reflect the view of the sponsors.

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CHAPTER 1: INTRODUCTION

1.1 Background

Low visibility roadway conditions caused by fog or smoke is one of the major traffic safety concerns. Florida has one of the most serious problem of fog/smoke (FS) related crashes in the United States. The reduced visibility condition can significantly affect the drivers' ability to drive safely and avoid road hazards. Driving in fog conditions is very risky because it may affect the awareness of speed and headway. It should be pointed out that reduced visibility has a significant effect on drivers' perception of road geometry and signs. For instance, drivers under low visibility conditions may not be able to observe the road curvature. In addition, it may cause lane departure, or even loss control of the vehicles.

It is known that under low visibility conditions, such as fog and smoke, crashes tend to be more severe than the crashes happened under normal clear conditions. Among all kinds of fog-related crashes, single-vehicle crashes including run-off-road crashes and rollover crashes have higher severity levels (Figure 2-1). Identifying the contributing factors and their relationships with the single-vehicle crashes under fog conditions is necessary. In addition, understanding the relationships between those factors can also be helpful to develop countermeasures to improve traffic safety and driver performance under reduced visibility conditions.

Recent years, connected-vehicle technologies have been widely discussed in traffic safety studies. It is believed that the connected-vehicle technologies will significantly reduce crash risk. Moreover, in-vehicle devices based on Augmented Reality (AR), such as Head-Up Display (HUD), have been equipped in the vehicles produced in recent years. Combination of the connected-vehicle technologies and the advanced in-vehicle devices is expected to bring huge benefits to road users. In addition, it will help drivers to drive safely in reduced visibility conditions.

1.2 Thesis Organization

This thesis contains four chapters. The first chapter is an introductory chapter including background and organization of the thesis.

In the second chapter, an analysis was conducted based a data mining technique, association rules mining, to identify the contributing factors and their relationships. Some countermeasures are provided to reduce the risk of fog-related single-vehicle crashes.

In the third chapter, driving simulator experiments were designed to evaluate how drivers respond to low visibility warning system using an in-vehicle Head-Up Display (HUD).

The last chapter reviewed the research findings and discussed the future research topics.

CHAPTER 2: EXAMINE PATTERNS OF FOG-RELATED SINGLE VEHICLE CRASHES SEVERITY USING ASSOCIATION RULES MINING

2.1 Introduction

Previous studies showed that fog/smoke related crashes have higher injury severity. However, most of these studies are more concentrated on the crash risk of rear-end crashes. We revisit the crash type and crash severity as shown in Figure 2-1. We can observe that rear-end and run-off-road crashes are the most common fog-related crash types. Nevertheless, as for the crash severity, we can see that the run-off-road crashes have more fatality and incapacitating injury, while only one vehicle involves in each crash. Similarly, the rollover crashes and single-vehicle crashes also have high injury severity. Since we were inspired by the high injury severity level of single-vehicle crashes, in this research, we analyzed the contributing factors of the fog-related single-vehicle crashes using association rules.

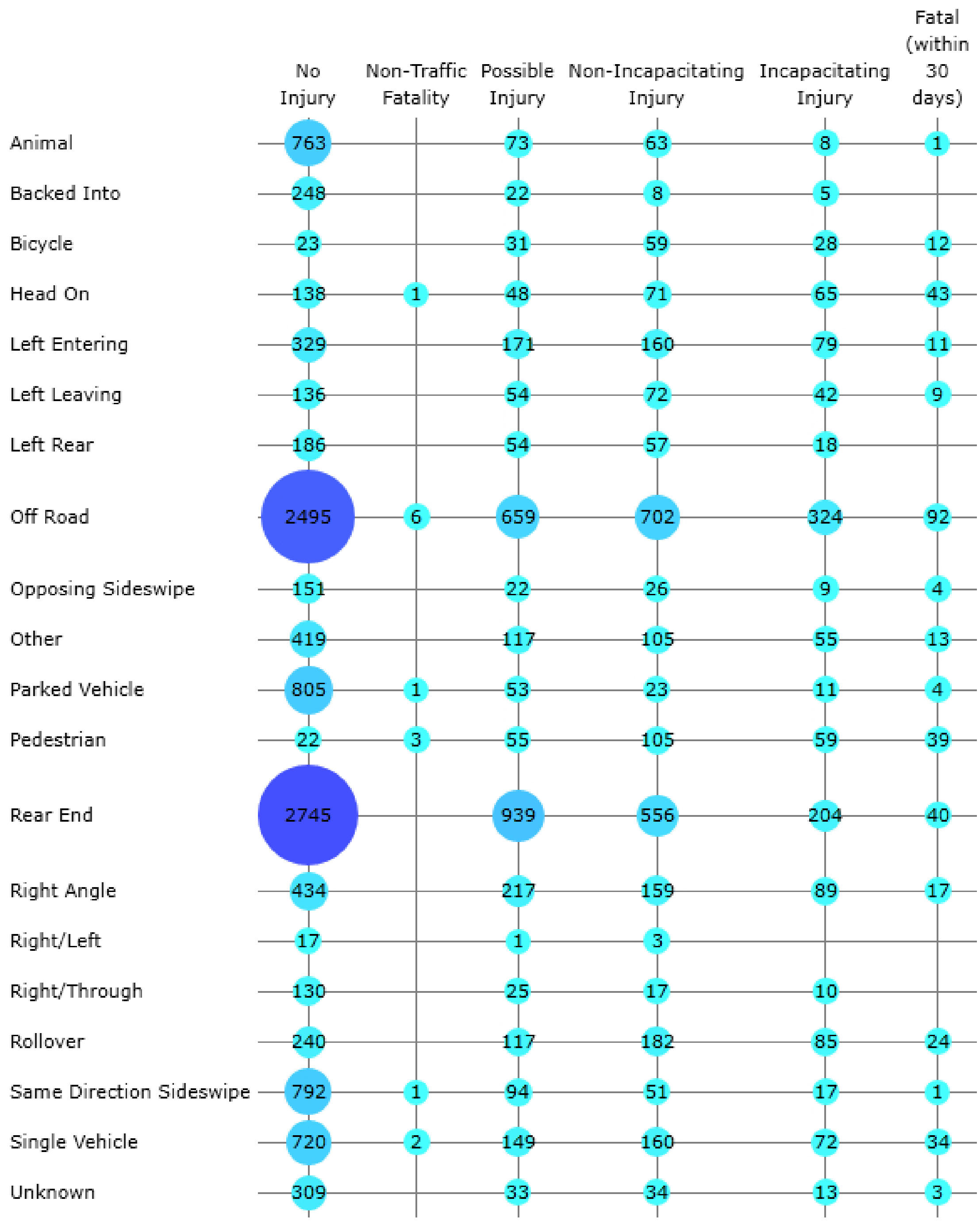

Figure 2-1 Fog-related crash type-severity chart

(Source: https://s4.geoplan.ufl.edu/, from 01/01/2006 to 07/22/2017)

2.2 Literature Review

To date, many studies focused on the crash risk and severity of single-vehicle crashes. Renski et al. (1999) investigated the effect of speed limit increases on single-vehicle crash severity on North Carolina's Interstate Highways. They found certain increase of speed limit would increase the probability of sustaining minor and non-incapacitating injuries. Chang and Yeh (2006) compared risk factors for driver fatalities in single-vehicle crashes between non-motorcycle drivers and motorcyclists. They found motorcyclists had approximately three times higher fatality risk than non-motorcycle drivers, Islam and Mannering (2006) explored the differences in single-vehicle injury severity between male and female drivers, and in different age groups. Their result shows that there are significant differences in the factors that determine injury-severity levels between different drivers' gender groups and age groups. Savolainen and Mannering (2007) estimated probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes. Jiang et al. (2013) investigated the influence of curbs on single-vehicle crash injury severity using zero-inflated ordered probit models. They found that the presence of curbs is likely to decrease incapacitating injury and fatality involved single-vehicle crashes. Jung et al. (2014) investigated the rain effect on single vehicle crash severities using polychotomous response models. Their results show that rainfall intensity, wind speed, roadway terrain, driver's gender, and safety belt are statistically significant for predicting crash severities. Shaheed and Gkritza (2014) examined the factors affecting single-vehicle motorcycle crash severity outcomes using latent class multinomial logit model. However, there is no previous study, which focused on single-vehicle crashes under fog conditions.

Although many previous studies have investigated the crash risk of fog-related crashes, few studies have attempted to explore the crash severity of certain crash type. Abdel-Aty et al. (2011) presented a comprehensive examination of fog/smoke-related crashes using crash data in Florida from 2003 to 2007. They analyzed the time distribution, influential factors and crash types. They found Fog/Smoke related crashes tend to result in more severe injuries and involve more vehicles. Ahmed et al. (2014) proposed a real-time fog-related crash prediction model using the airport weather data. Abdel-Aty et al. (2014) investigated the relationship between reduced visibility and traffic flow characteristics. Wu et al. (2016) investigated the changes of traffic characteristics and crash risks during fog conditions using real-time traffic flow and weather data. The results show that the crash risk was prone to increase at ramp vicinities during fog. Wu et al. (2017a) developed an algorithm for car-following behavior under fog conditions. Their results indicate that larger minimum comfortable and safe required gaps are needed with higher speed and lower visibility. Wu et al. (2018a) developed an algorithm to assess the rear-end collision risk under fog conditions using real-time data.

The association rule miming is a popular data mining method that can be available for safety analysis in recent years. Geurts et al. (2005) used frequent item sets mining (i.e., association rules mining) to understand the crash patterns of the “black zones”. Pande and Abdel-Aty (2009) analyzed crashes as transactions data to detect interdependence among crash characteristics and discussed the potential of this data mining methodology as a decision support tool for traffic safety analysis. Montella (2011) identified crash contributory factors at urban roundabouts and used the association rule approach to explore their relationship on different crash types. Montella et al. (2012) investigated powered two-wheeler crashes in Italy by classification trees and rules discovery approaches. Weng et al. (2016) investigated work zone crash casualty patterns using association rules. Das et al. (2017) used association rules to analyze pedestrian crashes.

In general, association rules mining can deal with high dimensional data and it can interpret the relationships of frequent variables under given support and confidence value. Compared with the parametric models, there is no dependent variable and functional forms in association rules mining. Moreover, the association rule could reflect the fact that risk factors may exhibit heterogeneous or hidden effects at various circumstances. Compared with the non-parametric models (e.g., tree-based models, neural networks), association rules have the advantage that it is also applicable on small datasets.

The aim of this study is to examine the contributing factors for different severity levels of fog-related single-vehicle crashes. First, the study introduces some descriptive statistics to analyze the status quo of fog-related single-vehicle crashes. Then, we employed association rules mining to analyze and compare the contributing factors of different severity level. The contributions of this paper are twofold. First, we proved that single-vehicle crashes are a major crash type in fog crashes with the highest crash severity. Second, we used the crash outcome as the consequent to generate association rules, which is easier to understand in safety analysis.

2.3 Methodology

2.3.1 Association rules mining

Association rules mining is a popular technique for discovering relations of variables in large datasets. Compared with other data mining methods, association rules mining is more scalable because it does not require any dependent variables and it has no requirement for the sample size. Moreover, the association rules are much easier to understand compared with other statistical methods. We can take related countermeasures to break the association between variables to eliminate the crash risk. For example, association rules like {Light_Condition=Dark-Not Lighted, VEHBDYTYP=Truck/Bus} => {HIGHESTINJ=KA} indicates that when the light condition is dark and unlighted, trucks or buses are easy to be involved in fatal/incapacitating injury crashes. Based on this association rule, we can install or improve road lighting in areas susceptible to fog to prevent the potential truck/bus crashes. We can also improve professional drivers' training for these conditions.

There are several algorithms available for association rules mining, such as the Apriori algorithm, Eclat algorithm and FP-tree. In this research, we chose the Apriori algorithm to explore the association rules of contributing factors in the single-vehicle crashes under fog conditions. The Apriori algorithm was first introduced by Agrawal et al. to discover association rules in large database in 1993. The algorithm can be interpreted as following:

Let $I = \{i_1, i_2,\ldots,i_n\}$ be a set of attributes, which are also called as items. Let $D = \{t_1, t_2,\ldots,t_m\}$ be a set of fog-related single-vehicle crash data called the database. Each crash in D contains a subset of the items in I. A rule is defined as an implication of the form $X \Longrightarrow Y$ where

$X, Y \subseteq I$ and $X \cap Y = \emptyset$. The sets of itemsets X and Y are called antecedent (left-hand-side, LHS) and consequent (right-hand-side, RHS) of the rule.

2.3.2 Discovering Interesting rules

There are 3 measures which are most commonly used to select the interesting rules: support, confidence and lift (Hashler et al., 2009). The support $supp(X)$ of an itemset X is defined as the proportion of crashes in the dataset, which contain the itemset:

$$supp(X) = \|\{t \in D | X \subseteq t\}\| / \|\{\mathrm{t} \in \mathrm{D}\}\|$$

The confidence $conf(X \Rightarrow Y)$ of a rule is defined as:

$$conf(X \Rightarrow Y) = supp(X \cup Y) / supp(X)$$

The confidence can be interpreted as an estimate of the probability $P(Y|X)$, which means finding the consequent of one rule in casualties under the condition of these crashes also include the antecedent.

The most common and practical measure to rank the found rules is lift (Brin et al., 1997). Higher lift value indicates stronger association. The lift $lift(X \Rightarrow Y)$ of a rule can be calculated by:

$$lift(X \Rightarrow Y) = supp(X \cup Y) / (supp(X) supp(Y))$$

In general, a lift greater than 1 indicates that the antecedent and consequent are dependent on each other, which means this rule can be useful for predicting the consequent in future datasets.

Moreover, an association rule $X \Rightarrow Y$ will satisfy:

$$supp(X \cup Y) \geq \sigma$$

and

$$conf(X \cup Y) \geq \delta$$

where σ and δ are the minimum support and minimum confidence, respectively

2.4 Data Preparation

This study aims to identify the changes of traffic characteristics and investigate the situations in which crash risk are more likely to increase during fog. A comparative analysis of the traffic patterns between fog and clear conditions was conducted by the traffic data and the weather data. The results reveal that the average volume and the average speed become lower under fog conditions.

The crash data were collected from Signal Four Analytics (S4A, https://s4.geoplan.ufl.edu/), which is developed by the University of Florida and Florida's Traffic Records Coordinating Committee (TRCC). We selected the fog-related crashes from 2011 to 2014 in Florida. Afterwards, we selected 3 types of single crashes: off-road, rollover, and other single that the number of vehicle is 1. Since S4A data did not provide downloadable detailed crash severity information, vehicle information, and occupants information, we joined related information from the CAR (Crash Analysis Reporting) data, maintained by FDOT.

After joining and re-categorizing the crash data, we finally got 1628 crashes records (Table 2-1). We separated the variables into three categories: driver information, crash and vehicle information, environment and traffic characteristics. Based on the frequency, we can make some simple conclusions. As for driver's information, it seems that young drivers (less than 25 years old) are more prone to be involved in fog-related single-vehicle crashes. Male drivers are much more likely to be involved in fog-related single vehicle crashes. Most of them are involved in lane departure crashes. As for the crash information, most crashes happened in midnight or early morning. Moreover, run-off-road crashes are the most common fog-related single-vehicle crashes. Collision with fixed object is the most harmful event in most of the crashes. As for the environment and traffic characteristics, most of the fog-related single-vehicle crashes occurred in dark conditions, especially on unlighted roadways. More crashes happened on county/local roads with undivided roadway. Most of the crashes happened on roadways with no traffic control devices and no more than two lanes on which the vehicle was being driven at the time of the crash.

Table 2-1 Data Description

Variable	Details	Frequency	Percentage
Driver's information			
RESTRAINT_HELMET	Unknown	103	6.3
	None	144	8.8
	Only	24	1.5
	Used	1357	83.4
DRIVER_CONDITION	Unknown	196	12
	Normal	1090	67
	Unnormal	342	21
AGE	<25	527	32.4
	>=65	71	4.4
	25-64	977	60
	Unknown	53	3.3
GENDER	Female	496	30.5
	Male	1088	66.8
	Unknown	44	2.7
FL_LANEDEP	N	476	29.2
	Y	1152	70.8
FL_AGGRSV	N	1593	97.9
	Y	35	2.1
ALCOHOL_RELATED	N	1384	85
	Y	244	15
DISTRACTION_RELATED	N	1402	86.1
	Y	226	13.9
DRUG_RELATED	N	1596	98
	Y	32	2
Crash and vehicle information			
WEEK	Weekday	1159	71.2
	Weekend	469	28.8
TIME	0:00-6:00	821	50.4
	12:00-18:00	29	1.8
	18:00-24:00	213	13.1
	6:00-12:00	565	34.7
CRASH_TYPE	Off Road	1122	68.9
	Other Single	278	17.1
	Rollover	228	14
FIRST_HE_LOCATION	Gore/Median	97	6
	Off Roadway	755	46.4
	On Roadway	319	19.6
	Others	22	1.4
	Shoulder	435	26.7
HRMFL_MOST	Collision non-fixed object	139	8.5
	Collision with fixed object	1065	65.4
	Unknown	51	3.1
	Non-collision	361	22.2
	Sequence of Events	12	0.7
VEHBDYTYP	Motorcycle/Moped/ATV	76	4.7
	Unknown	20	1.2
	Passenger car/Pickup	1432	88
	Truck/Bus(large-sized)	100	6.1

Variable	Details	Frequency	Percentage
VEHICLEMOV	Unknown	68	4.2
	Negotiating a curve	138	8.5
	Others	99	6.1
	Straight ahead	1201	73.8
	Turning	122	7.5
HIGHESTINJ	BC	630	38.7
	KA	182	11.2
	O	816	50.1
FLAG_INT	N	1224	75.2
	Y	404	24.8
Environment and traffic characteristics			
LIGHT_CONDITION	Dark - Lighted	377	23.2
	Dark - Not Lighted	740	45.5
	Dawn/Dusk	221	13.6
	Daylight	278	17.1
	Unknown	12	0.7
WITHIN_CITY_LIMITS	N	1205	74
	Y	423	26
ROAD_SYS_IDENTIFIER	County/Local	935	57.4
	FL State Highway System	688	42.3
	Unknown	5	0.3
TYPE_OF_SHOULDER	Curb	226	13.9
	Paved	464	28.5
	Unpaved	938	57.6
ROAD_SURF_COND	Dry	1032	63.4
	Unknown	6	0.4
	Poor	30	1.8
	Wet	560	34.4
RDWYSPEED	<40mph	497	30.5
	>60mph	245	15
	40-60mph	845	51.9
	Unknown	41	2.5
TOTALLANES	>=4	466	28.6
	1	73	4.5
	2	1044	64.1
	3	26	1.6
	Unknown	19	1.2
TRAFFICWAY	Divided	534	32.8
	Unknown	74	4.5
	Undivided	1020	62.7
VEHTRAFTCD	Unknown	73	4.5
	None	1260	77.4
	Railroad cross	3	0.2
	Stop/Yield/War	193	11.9
	Traffic signal	99	6.1

2.5 Result and Discussion

We separate our analysis into 3 parts based on the different severity levels: fatal and incapacitating injury (KA), non-incapacitating injury and possible injury (BC), and property damage only (O). We select the injury levels as the consequents of the association rules. Therefore, the antecedents can be interpreted as the potential contributing factors. The association rules were generated using the R package 'arules' (Hahsler et al, 2009).

2.5.1 Association rules for fatal and incapacitating injury (KA) crashes

In this part, we mainly investigate the association rules for the highest injury level. We set the {HIGHESTINJ=KA} as the consequents to generate association rules. The minimum support σ and minimum confidence δ are set to be 0.003 and 0.5, respectively. In addition, the maximum length of association rules was set to 4. The minimum support of 0.003 indicates that each association rule at least represents 5 crashes in the crash dataset ($1628*0.003\approx5$). After excluding redundant rules and the rules with lift less than 1.0, we finally obtained 5 rules (Table 2-2).

Based on the obtained rules, we can reach the following conclusions (Table 2-3). Female drivers are more likely involved in severe fog-related single-vehicle crashes at gore or median on the roadway with unpaved shoulder. The severe fog-related single vehicle crashes are related to drivers' lane departure and aggressive driving behavior on local roads, mostly not related to intersections. In addition, two-lane roads with wet pavement are potential contributing factors for severe fog-related single-vehicle crashes. Larger vehicles like trucks or buses are more prone to be involved in severe fog-related single vehicle crashes under dark conditions without light.

Table 2-2 Association rules for KA crashes

No.	LHS	RHS	support	confidence	lift
1	{First_HE_Location=Gore/Median, Type_of_Shoulder=Unpaved, GENDER=Female}	{HIGHESTINJ=KA}	0.003	0.56	4.97
2	{Road_Sys_Identifier=County/Local, FL_LANEDEP=Y, FL_AGGRSV=Y}	{HIGHESTINJ=KA}	0.004	0.55	4.88
3	{Road_Sys_Identifier=County/Local, FLAG_INT=N, FL_AGGRSV=Y}	{HIGHESTINJ=KA}	0.004	0.55	4.88
4	{Light_Condition=Daylight, Road_Surf_Cond=Wet, TOTALLANES=1}	{HIGHESTINJ=KA}	0.004	0.50	4.47
5	{Light_Condition=Dark - Not Lighted, First_HE_Location=On Roadway, VEHBDYTYP=Truck/Bus(large-sized)}	{HIGHESTINJ=KA}	0.004	0.50	4.47

Table 2-3 Interpretation of association rules for KA crashes

No.	Contribution Factors	Injury Level
1	First harmful location is gore/median + Unpaved Shoulder + Female Driver	Killed/Incapacitating injury
2	City/Local road + Lane departure + Aggressive driving	Killed/Incapacitating injury
3	City/Local road + Not at intersection + Aggressive driving	Killed/Incapacitating injury
4	Daylight + Wet road surface + One-lane road	Killed/Incapacitating injury
5	Dark and not lighted + First harmful on location is roadway + Large truck/Bus	Killed/Incapacitating injury

2.5.2 Association rules for non-incapacitating injury and possible injury (BC) crashes

In the second part, we mainly investigate the association rules for the non-incapacitating injury and possible injury (BC) fog-related single vehicle crashes. We set the {HIGHESTINJ=BC} as the consequents to discover association rules. The minimum support σ and minimum confidence δ are set to be 0.02 and 0.5, respectively. The maximum length of association rules was set to 4. After excluding redundant rules and the rules with lift less than 1.0, we finally achieved 42 rules. We list the 10 rules with highest lift value for analysis in Table 2-4.

Based on the obtained rules for BC fog-related single vehicle crashes, we can reach the following conclusions (Table 2-5). Distracted drivers are more likely to be involved in BC fog-related single vehicle crashes, especially for female drivers. Other contributing factors of distraction related to BC fog-related single-vehicle crashes include non-traffic control, undivided traffic way and young drivers. The BC fog-related single vehicle crashes are more likely to happen on local roads in rural area in the evening. Lane departure with high speed when turning is still the main contributing factor to BC fog-related single vehicle crashes. Dark lighting conditions and wet road surface are also potential contributing factors.

Table 2-4 Association rules for BC crashes

No.	LHS	RS	support	confidence	lift
1	{Distraction_Related=Y, RESTRAINT_HELMET=Used, GENDER=Female}	{HIGHESTINJ=BC}	0.021	0.56	1.44
2	{Time=18:00-24:00, Within_City_Limits=N, Road_Sys_Identifier=County/Local}	{HIGHESTINJ=BC}	0.028	0.55	1.42
3	{Week=Weekday, VEHICLEMOV=Turning, FL_LANEDEP=Y}	{HIGHESTINJ=BC}	0.021	0.55	1.41
4	{Distraction_Related=Y, Drug_Related=N, GENDER=Female}	{HIGHESTINJ=BC}	0.022	0.54	1.39
5	{Crash_Type=Off Road, Distraction_Related=Y, VEHTRAFTCD=None}	{HIGHESTINJ=BC}	0.037	0.54	1.38
6	{Week=Weekday, VEHICLEMOV=Negotiating a curve, FL_LANEDEP=Y}	{HIGHESTINJ=BC}	0.020	0.53	1.38
7	{Distraction_Related=Y, TRAFFICWAY=Undivided, AGE=<25}	{HIGHESTINJ=BC}	0.021	0.53	1.37
8	{Week=Weekday, VEHICLEMOV=Turning, FLAG_INT=N}	{HIGHESTINJ=BC}	0.022	0.53	1.37
9	{Light_Condition=Dark - Lighted, Road_Sys_Identifier=County/Local, Road_Surf_Cond=Wet}	{HIGHESTINJ=BC}	0.023	0.53	1.36
10	{Light_Condition=Dark - Not Lighted, AGE=<25, GENDER=Female}	{HIGHESTINJ=BC}	0.025	0.53	1.36

Table 2-5 Interpretation of association rules for KA crashes

No.	Contribution Factors	Injury Level
1	Distracted driving + Use belt/helmet + Female driver	Non-incapacitating injury/Possible Injury
2	6pm-0am + Within city + County/Local road	Non-incapacitating injury/Possible Injury
3	Weekday + Vehicle turning + Lane departure	Non-incapacitating injury/Possible Injury
4	Distracted driving + Drug related + Female driver	Non-incapacitating injury/Possible Injury
5	Run-off-road crash + Distracted driving + No traffic control devices	Non-incapacitating injury/Possible Injury
6	Weekday + Vehicle negotiating a curve + Lane departure	Non-incapacitating injury/Possible Injury
7	Distracted driving + Undivided trafficway + Driver's age<=25	Non-incapacitating injury/Possible Injury
8	Weekday + Vehicle turning + Not related to intersection	Non-incapacitating injury/Possible Injury
9	Dark lighted + County/Local road +Wet road surface	Non-incapacitating injury/Possible Injury
10	Dark not lighted + Driver's age<=25 + Female driver	Non-incapacitating injury/Possible Injury

2.5.3 Association rules for property damage only (PDO) crashes

In the third part, we investigate the association rules for the property damage only (PDO) fog-related single-vehicle crashes. We set the {HIGHESTINJ=O} as the consequents to discover the association rules. The minimum support σ and minimum confidence δ are set to be 0.15 and 0.5, respectively. The maximum length of association rules was set to 4. After excluding redundant rules and the rules with lift less than 1.0, we finally had 174 rules. We listed the 10 rules with highest lift value for analysis in Table 2-6.

Based on the rules for PDO fog-related single-vehicle crashes, we can reach the following conclusions (Table 2-7). The PDO fog-related single-vehicle crashes are not correlated with lane departure and aggressive driving. In addition, the crashes are more likely to happen on the State

Highway Systems (SHS), while the pavement is dry, and the vehicle motion is straight ahead. The PDO fog-related single-vehicle crashes are more likely to happen on divided highways.

Table 2-6 Association rules for PDO crashes

No.	LHS	RHS	Support	Confidence	Lift
1	{FL_LANEDEP=N,FL_AGGRSV=N}	{HIGHESTINJ=O}	0.162	0.57	1.14
2	{FL_LANEDEP=N}	{HIGHESTINJ=O}	0.165	0.56	1.12
3	{Within_City_Limits=N, Road_Sys_Identifier=FL State Highway System, VEHBDYTYP=Passenger car/Pickup}	{HIGHESTINJ=O}	0.157	0.55	1.09
4	{Road_Surf_Cond=Dry, VEHICLEMOV=Straight ahead, AGE=25-64}	{HIGHESTINJ=O}	0.160	0.54	1.09
5	{VEHBDYTYP=Passenger car/Pickup, RDWYSPEED=40-60mph, GENDER=Male}	{HIGHESTINJ=O}	0.163	0.54	1.08
6	{Road_Sys_Identifier=FL State Highway System, VEHBDYTYP=Passenger car/Pickup, VEHICLEMOV=Straight ahead}	{HIGHESTINJ=O}	0.157	0.54	1.08
7	{Alcohol_Related=N, Within_City_Limits=N, Road_Sys_Identifier=FL State Highway System}	{HIGHESTINJ=O}	0.154	0.54	1.07
8	{First_HE_Location=Off Roadway, GENDER=Male, FL_AGGRSV=N}	{HIGHESTINJ=O}	0.160	0.54	1.07
9	{Drug_Related=N, VEHBDYTYP=Passenger car/Pickup, TRAFFICWAY=Divided}	{HIGHESTINJ=O}	0.152	0.54	1.07
10	{Drug_Related=N, TRAFFICWAY=Divided, RESTRAINT_HELMET=Used}	{HIGHESTINJ=O}	0.153	0.54	1.07

Table 2-7 Interpretation of association rules for PDO crashes

No.	Contribution Factors	Injury Level
1	No lane departure + No aggressive driving	Property Damage Only
2	No lane departure	Property Damage Only
3	Within city + FL State highway + Passenger car/Pickup	Property Damage Only
4	Dry road surface + Vehicle straight ahead + Driver's age: 25 to 64	Property Damage Only
5	Passenger car/Pickup + Speed limit: 40-60mph + Male driver	Property Damage Only
6	FL State highway + Passenger car/Pickup + Vehicle straight ahead	Property Damage Only
7	Not alcohol related+ Within city + FL State highway	Property Damage Only
8	First harmful location is off road + Male driver + No aggressive driving	Property Damage Only
9	Not drug related + Passenger car/Pickup +Divided trafficway	Property Damage Only
10	Not drug related + Divided trafficway + Belt/helmet used	Property Damage Only

2.6 Summary

Mining association rules can provide the relationship of the contributing factors based on the presented consequents we need. Moreover, it is easy to implement and regardless of the size of data. We can get some insight from different groups of association rules. After comparing the association rules in the three crash severity categories, we can summarize some key contributing factors to severe fog-related single vehicle crashes. The lane departure and aggressive driving are two main contributing factors for severe fog-related single vehicle crashes. Wet road surface and dark without street lights can also be the contributing factors for severe crashes. Compared with PDO crashes, the injury crashes are more likely to happen on two-lane county/local roads, which have unpaved shoulders and less traffic control devices.

Related countermeasures can be taken to reduce the risk of severe crashes. First, it is necessary to install street lights at the hot spots of fog-related single vehicle crashes. Some visual enhanced road signs under fog conditions, such as self-luminous road signs, may help drivers to be better aware of the road curvature under fog conditions. In addition, advanced driver assistance system (ADAS), such as lane departure waring system, can reduce the severe crash risk. It is also necessary to educate drivers to realize the risk of driving under fog conditions.

CHAPTER 3: EVALUATING CURVE WARNING SYSTEM UNDER CONNECTED VEHICLES' ENVIRONMENT USING DRIVING SIMULATOR

3.1 Introduction

Driving simulation experiments continue to be one of most effective methods to investigate safety effect and solutions (Abdel-Aty et al., 2017; Cai et al., 2018). Driver's visual performance will affect the effectiveness of warning systems (Zhang et al., 2018). Wu et al. (2018) tested the effects of Connected-Vehicle warning systems on rear-end crash avoidance behavior under fog conditions. We have proved that lane departure at curve is one of the most important contributing factors to severe fog-related crashes. However, there is no sufficient research to investigate the effectiveness of curve warning systems to date. In this section, we investigated speed and lane departure behaviors at a curve segment affected by warning type, gender, and fog level. The warning type variable has three different levels, while the fog level variable includes two levels (Table 3-1). Drivers' lane departure conditions and their speeds will be recorded to analyze drivers' reactions under fog conditions. One-way ANOVA (Analysis of Variance) with repeated measures was employed to investigate the difference between independent experiment groups.

Table 3-1 Summary of scenario variables

Level	Slow Moving Vehicle Warning	Fog Level
0	Head-up display (HUD) with warning sound (Text: Curve ahead) (Images: Curve ahead)	Moderate fog (300 ft.)
1	Head-up display (HUD) without warning sound (Text: Curve ahead) (Images: Curve ahead)	Dense fog (100 ft.)
2	None	N/A

3.1.1 Experiment

The National Advanced Driving Simulator (NADS) MiniSim was used for the experiment (Figure 3-1). The simulator has three monitors with a 110-degree front field of view, which also include the left, middle, and right rear-view mirrors.

Figure 3-1 NADS MiniSim at UCF

Forty-eight subjects were recruited for this research (mean=38.44, SD=19.36). Each subject was required to hold a valid driver's license and have at least two years of driving experience. Upon arrival, each subject was briefly introduced the requirements of the experiment and asked to read and sign a consent form. The subjects were advised to drive as they normally did in real-life situations. Before the formal test, each subject performed a practice drive for at least 5 min to become familiar with the driving simulator. In this practice session, the subjects exercised maneuvers including straight driving, acceleration, deceleration, left/right turn, and other basic driving behaviors.

In addition, subjects were also notified that they could quit the experiment at any time in case of motion sickness or any kind of discomfort. The experiment was reviewed and approved by the University of Central Florida Institutional Review Board (IRB) (Appendix A).

3.1.2 Data Reduction

NADS now provides a functional MATLAB-based data reduction tool named ndaqTools (Figure 3-2). In this study, we used the NADS ndaqTools to run the data reduction process. We first generated the data disposition table as required. Then, we selected the elements list for the DAQ files based on the variables to be investigated. The frequency of data reduction was set to 60 Hz. Afterwards, we got the structured '.mat' files of the DAQ files generated by all the experiments. Lastly, the '.mat' files were transformed into '.csv' files in order to load the data file in statistical software and conduct analysis.

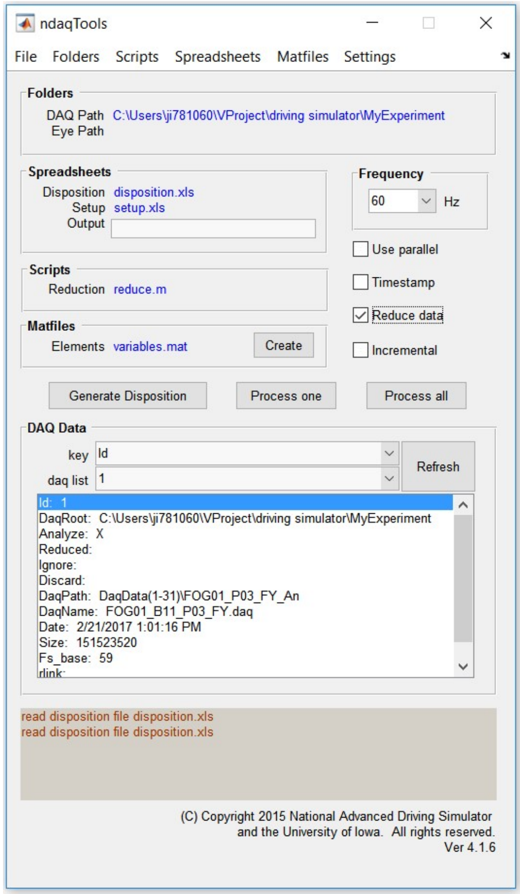

Figure 3-2 ndaqTools

3.1.3 Variable Selection

As it is shown in Table 3-2, warning type is the within-subject variable, and fog level is the between-subject variable for this experiment. The warning type has three levels (i.e., HUD &audio warning, HUD warning only, no warning). Meanwhile, fog level includes two levels (i.e. dense fog, moderate fog).

Table 3-2 Definitions of scenario-related variables and their codes

Name	Description
Warning Type	
WARNING	Warning=1: head-up display warning with audio warning; Warning=2: head-up display warning without audio warning; Warning=3: no warning.
Fog Level	
DENSE	Dense=1: dense fog; Dense=0: moderate fog.

In this study, the onset of the event is defined as follows: (1) if the scenario includes a HUD warning, then the event starts at the beginning of the warning; (2) otherwise, the event starts when the participant can see the lead vehicle, when the lead vehicle has started to decelerate.

The drivers' speed was used as one of the dependent variables in this study to evaluate drivers' behaviors. The other dependent variable that is utilized in this study is lane departure value. Lane departure information was calculated using the variable 'SCC_Lane_Deviation_2'. It means the offset from the center of the lane. Since the experiments were designed for a 4-lane divided arterial and the lane width is 12 feet (each direction has two lanes), the location of the center of the right lane in 'SCC_Lane_Deviation_2' should be three. Thus, the lane departure value can be calculated by:

$$\mathrm{Lndp} = \mathrm{abs}(\mathrm{SCC\_Lane\_Deviation\_2} - 3)$$

3.2 Average Lane departure

From the ANOVA result below (Table 3-3), there are significant differences in average lane departure between male and female. It shows that female drivers have higher average lane departure values (Figure 3-3). In addition, drivers have slightly better lane control ability in the scenarios with HUD and warning sound (Figure 3-4). The drivers have larger average lane departure values in dense fog scenarios (Figure 3-5).

Table 3-3 Tests of Between-Subjects Effects for Average Lane Departure

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
fog_level	.986	1	.986	.423	.519	.010	.423	.098
gender	12.541	1	12.541	5.381	.025*	.109	5.381	.621
fog_level * gender	4.612	1	4.612	1.979	.167	.043	1.979	.280
Error	102.547	44	2.331					
a. Computed using alpha = .05								

*significant at 0.05 significant level.

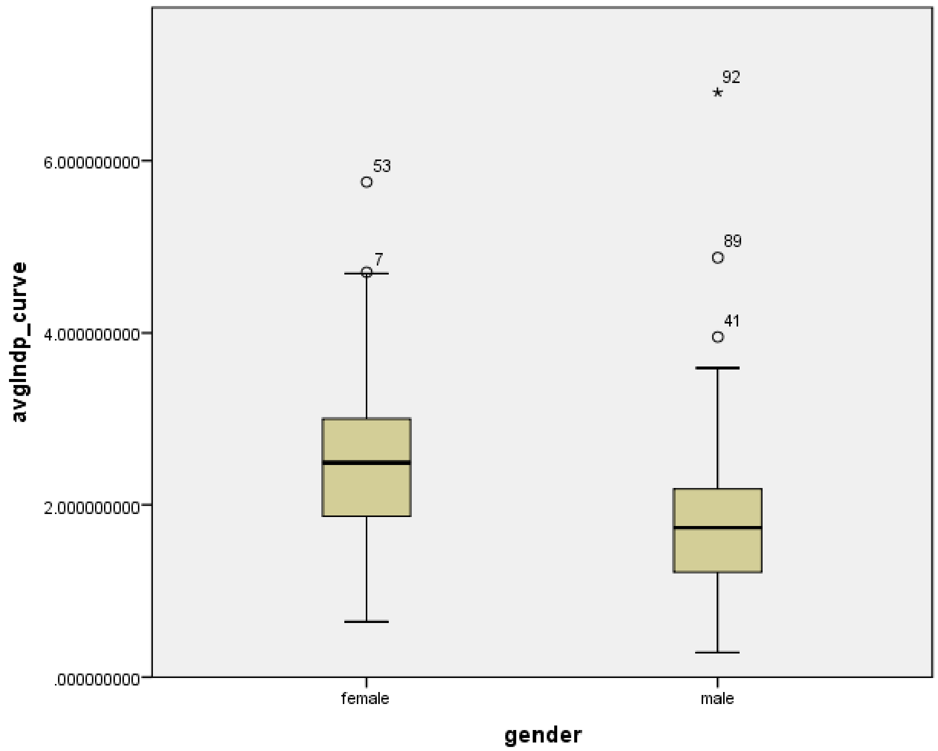

Figure 3-3 Box Plot for Average Lane Departure based on Gender

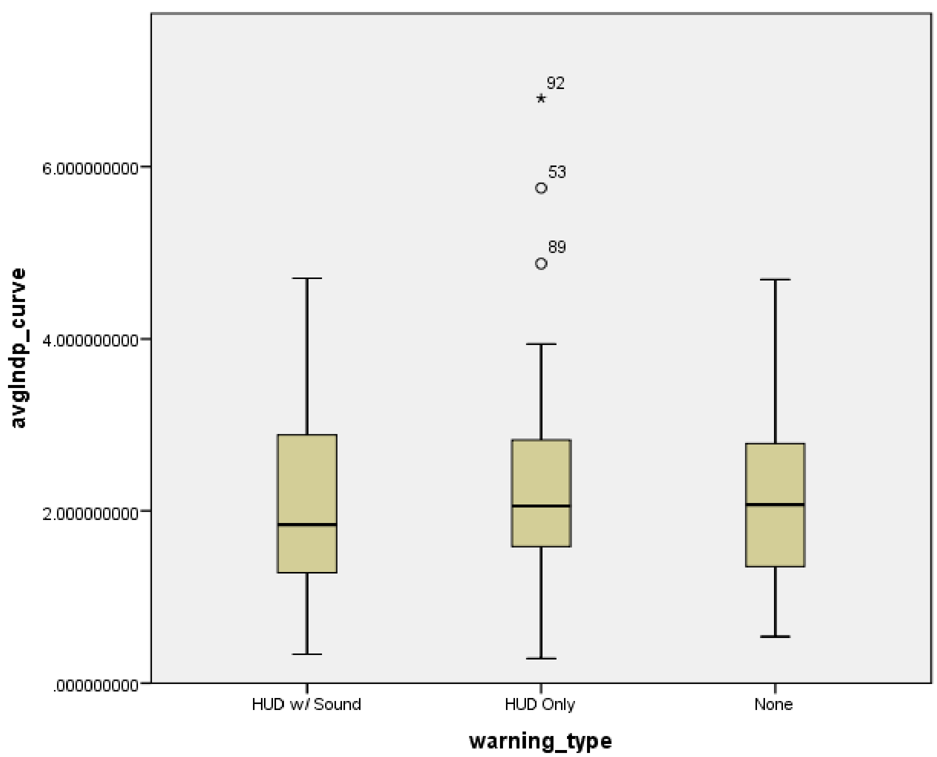

Figure 3-4 Box Plot for Average Lane Departure based on Warning Type

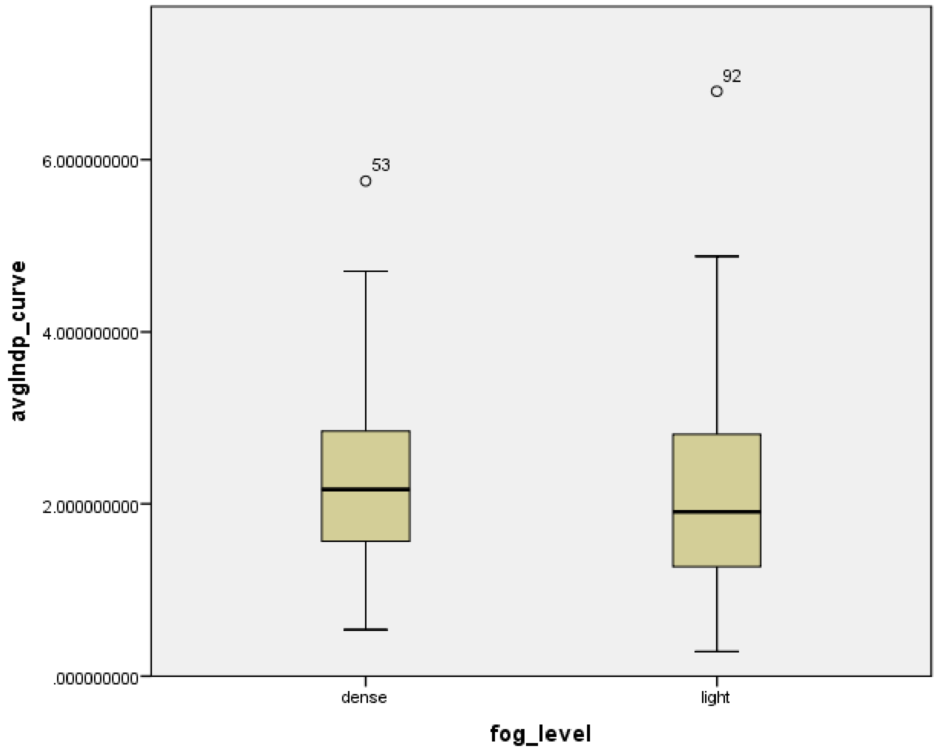

Figure 3-5 Box Plot for Average Lane Departure based on Fog Level

3.3 Maximum Lane Departure

From the ANOVA results below (Table 3-4), although there is no significant variable, we can still find some trends from the boxplots. Drivers have smaller maximum lane departure values in the scenarios with HUD and warning sound (Figure 3-4). The drivers have larger maximum lane departure in dense fog scenarios (Figure 3-5). Still, female drivers have larger maximum lane departure vales (Figure 3-6).

Table 3-4 Tests of Between-Subjects Effects Maximum Lane Departure

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
fog_level	.142	1	.142	.046	.831	.001	.046	.055
gender	9.172	1	9.172	2.968	.092	.063	2.968	.392
fog_level * gender	6.052	1	6.052	1.958	.169	.043	1.958	.278
Error	136.002	44	3.091					
a. Computed using alpha = .05								

*significant at 0.05 significant level;

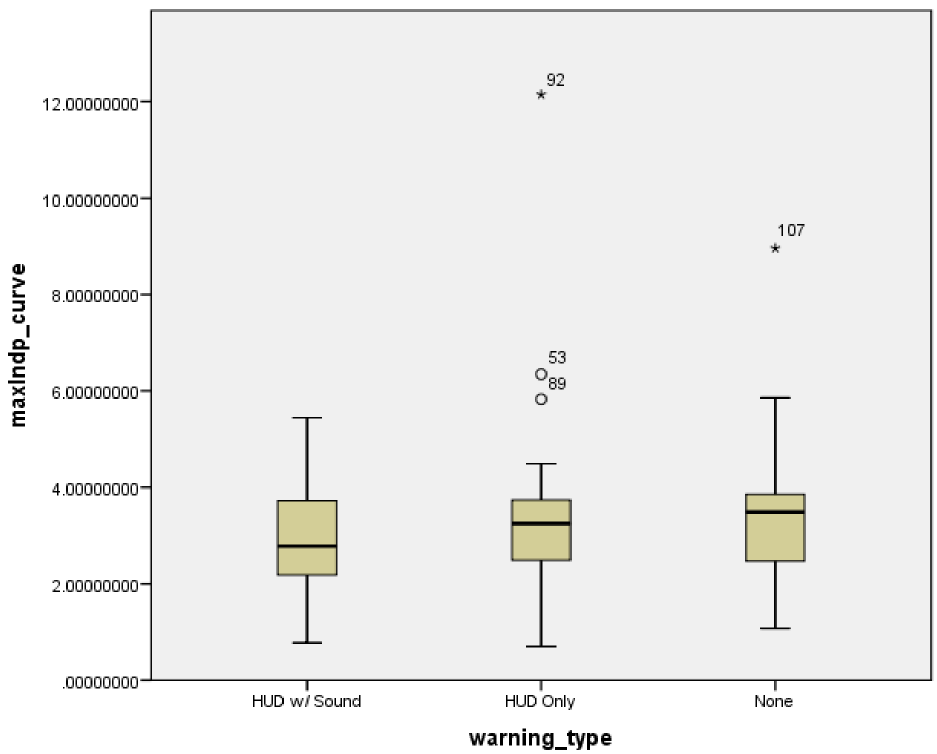

Figure 3-6 Box Plot for Maximum Lane Departure based on Warning Type

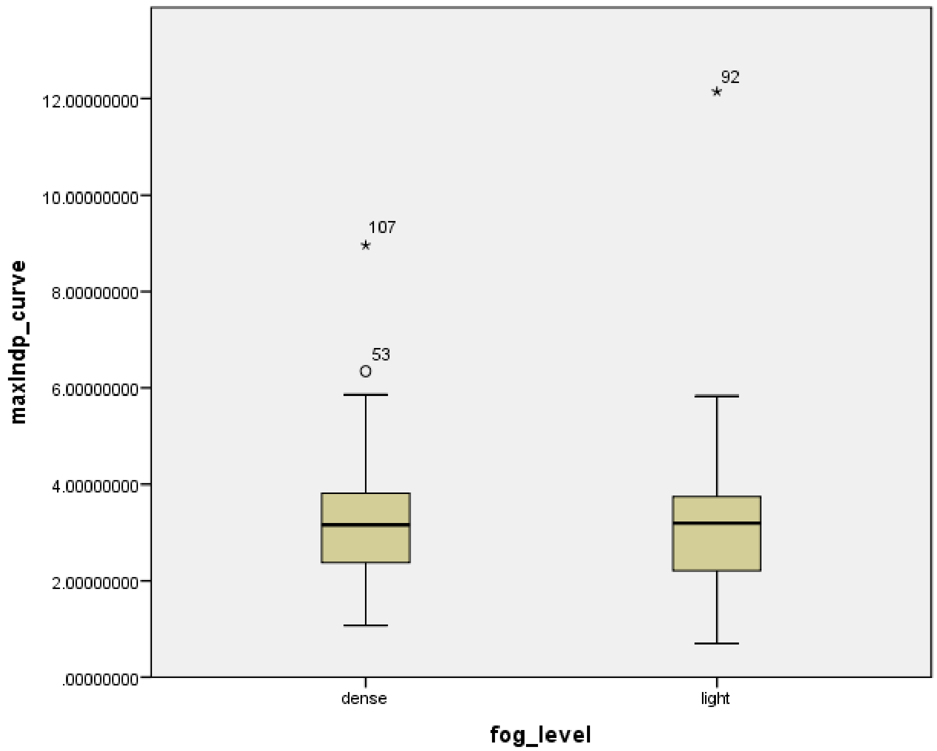

Figure 3-7 Box Plot for Maximum Lane Departure based on Fog Level

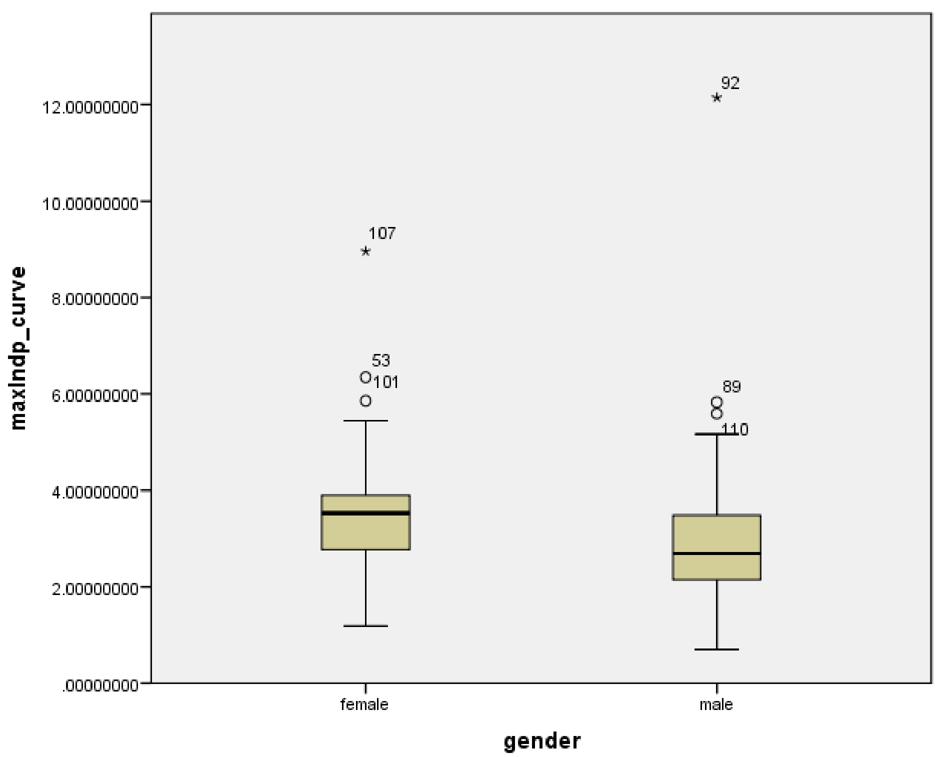

Figure 3-8 Box Plot for Maximum Lane Departure based on Gender

3.4 Average Speed at Curve Section

From the ANOVA result below (Table 3-5), we can conclude that there is a significant difference in the average speed between different fog levels. It shows that the average speed is higher in moderate fog condition (Figure 3-8). Drivers have slightly smaller average speed in the scenarios with HUD and warning sound (Figure 3-7). It is worthy of mentioning that male drivers tend to have higher speed under fog conditions, which indicates that male drivers may be more confidence of their driving skills when compared with female drivers.

Table 3-5 Tests of Between-Subjects Effects for Average Speed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	265811.119	1	265811.119	1783.428	.000	.976	1783.428	1.000
fog_level	757.542	1	757.542	5.083	.029*	.104	5.083	.597
gender	4.332	1	4.332	.029	.865	.001	.029	.053
fog_level * gender	29.626	1	29.626	.199	.658	.004	.199	.072
Error	6557.981	44	149.045					
a. Computed using alpha = .05								

*significant at 0.05 significant level;

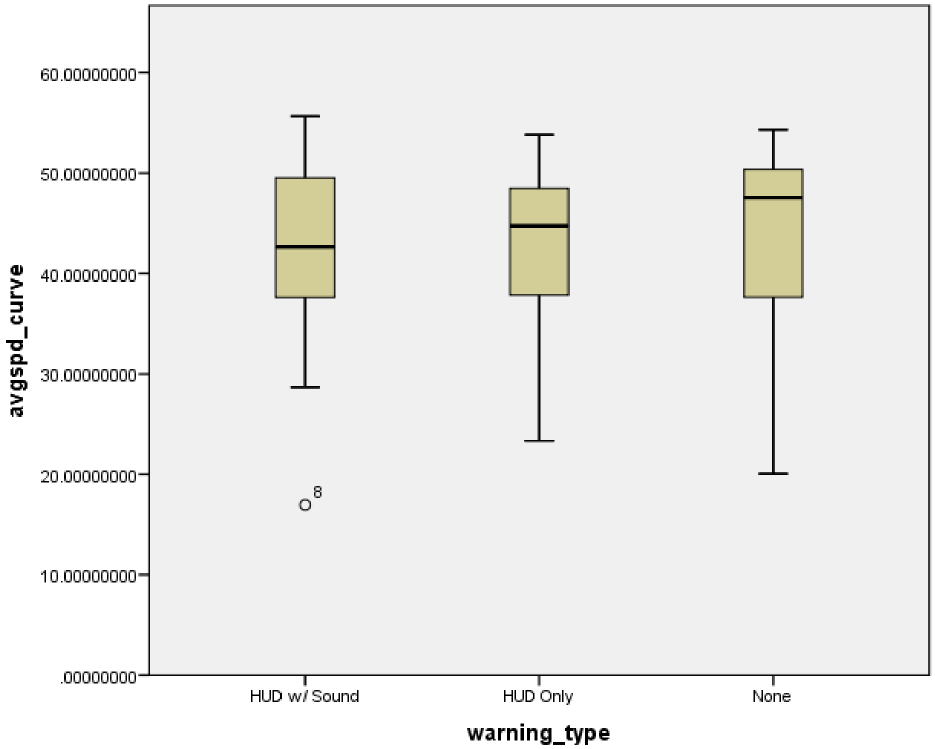

Figure 3-9 Box Plot for Average Speed based on Warning Type

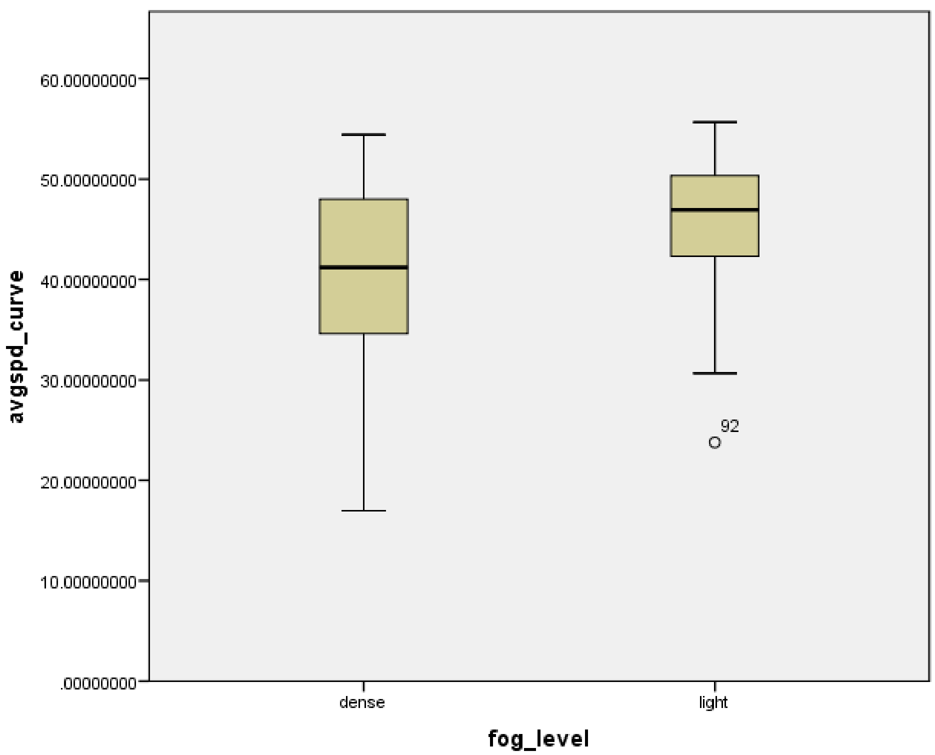

Figure 3-10 Box Plot for Average Speed based on Fog Level

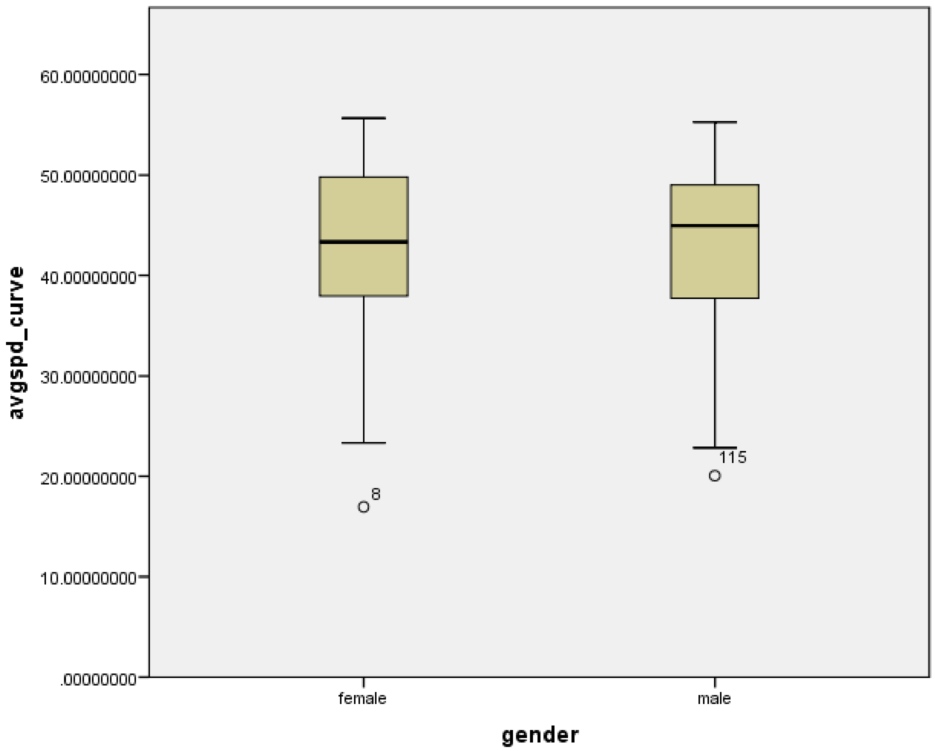

Figure 3-11 Box Plot for Average Speed based on Gender

3.5 Minimum Speed at Curve Section

From the ANOVA result below (Table 3-6 and Table 3-7), we can conclude that there is a significant difference in the minimum speed between different warning types, while the effect of gender is not significant (Figure 3-12). Meanwhile, driver at different age groups may have significant differences (Figure 3-13). Figure 3-14 shows that the minimum speeds are lower when HUD warnings presented. Moreover, the HUD warning with audio has the highest effectiveness when compared with other warning conditions.

Table 3-6 Tests of Within-Subjects Effects for Minimum Speed

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
warning_type	Sphericity Assumed	281.464	2	140.732	4.652	.012*	.096	9.304	.770
	Greenhouse-Geisser	281.464	1.887	149.158	4.652	.014*	.096	8.779	.752
	Huynh-Feldt	281.464	2.000	140.732	4.652	.012*	.096	9.304	.770
	Lower-bound	281.464	1.000	281.464	4.652	.037*	.096	4.652	.560
warning_type * fog_level	Sphericity Assumed	145.549	2	72.774	2.406	.096	.052	4.811	.474
	Greenhouse-Geisser	145.549	1.887	77.131	2.406	.100	.052	4.539	.459
	Huynh-Feldt	145.549	2.000	72.774	2.406	.096	.052	4.811	.474
	Lower-bound	145.549	1.000	145.549	2.406	.128	.052	2.406	.329
warning_type * gender	Sphericity Assumed	39.236	2	19.618	.648	.525	.015	1.297	.156
	Greenhouse-Geisser	39.236	1.887	20.792	.648	.517	.015	1.224	.152
	Huynh-Feldt	39.236	2.000	19.618	.648	.525	.015	1.297	.156
	Lower-bound	39.236	1.000	39.236	.648	.425	.015	.648	.124
warning_type * fog_level * gender	Sphericity Assumed	109.602	2	54.801	1.811	.169	.040	3.623	.369
	Greenhouse-Geisser	109.602	1.887	58.082	1.811	.172	.040	3.418	.358
	Huynh-Feldt	109.602	2.000	54.801	1.811	.169	.040	3.623	.369
	Lower-bound	109.602	1.000	109.602	1.811	.185	.040	1.811	.261
Error(warning_type)	Sphericity Assumed	2662.153	88	30.252					
	Greenhouse-Geisser	2662.153	83.029	32.063					
	Huynh-Feldt	2662.153	88.000	30.252					
	Lower-bound	2662.153	44.000	60.503					
a. Computed using alpha = .05									

*significant at 0.05 significant level;

Table 3-7 Tests of Between-Subjects Effects Minimum Speed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	217781.926	1	217781.926	1108.698	.000	.962	1108.698	1.000
fog_level	712.483	1	712.483	3.627	.063*	.076	3.627	.461
gender	.568	1	.568	.003	.957	.000	.003	.050
fog_level * gender	59.222	1	59.222	.301	.586	.007	.301	.084
Error	8642.937	44	196.430					
a. Computed using alpha = .05								

*significant at 0.05 significant level.

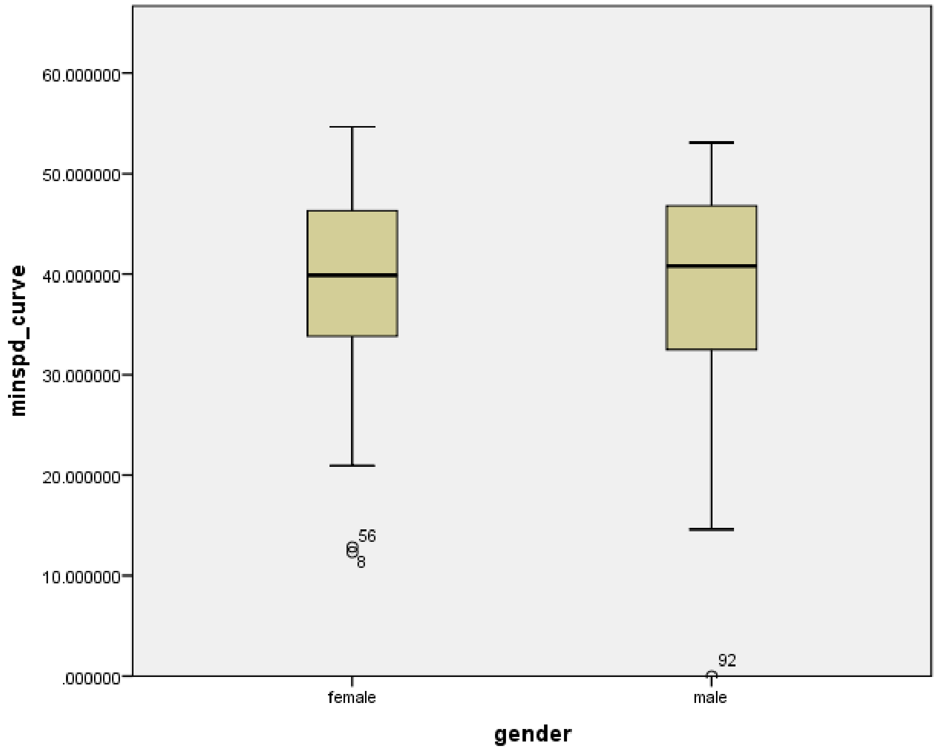

Figure 3-12 Box Plot for Minimum Speed based on Gender

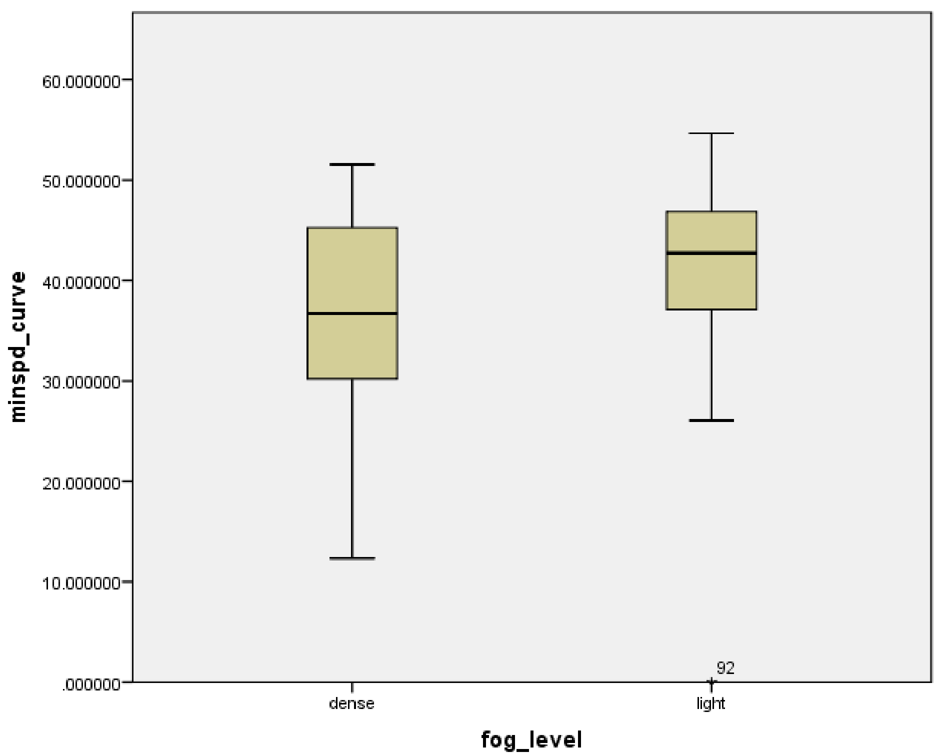

Figure 3-13 Box Plot for Minimum Speed based on Fog Level

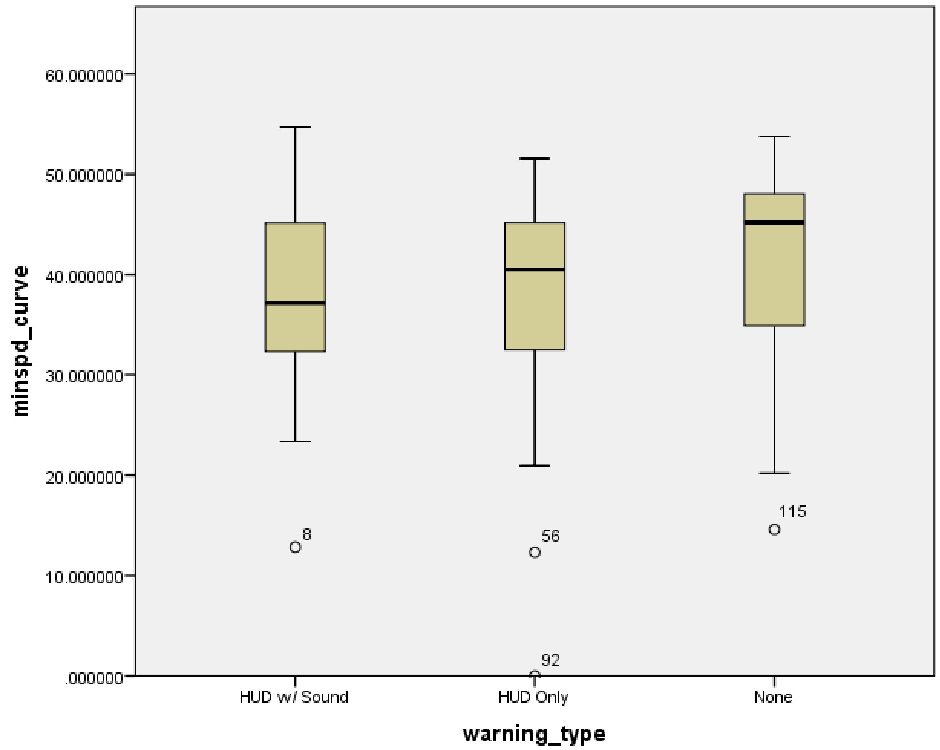

Figure 3-14 Box Plot for Minimum Speed based on Warning Type

3.6 Maximum Speed at Curve Section

From the ANOVA result below (Table 3-8), we can conclude that there is a significant difference in the maximum speed between different fog levels (Figure 3-15). As we can see from Figure 3-13, the maximum speeds are higher in moderate fog conditions. Meanwhile, no significant difference could be observed in different gender and warning groups (Figure 3-16 and Figure 3-17).

Table 3-8 Tests of Between-Subjects Effects for Maximum Speed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	322210.045	1	322210.045	2401.729	.000	.982	2401.729	1.000
fog_level	823.187	1	823.187	6.136	.017*	.122	6.136	.678
gender	7.669	1	7.669	.057	.812	.001	.057	.056
fog_level * gender	8.898	1	8.898	.066	.798	.002	.066	.057
Error	5902.933	44	134.158					
a. Computed using alpha = .05								

*significant at 0.05 significant level;

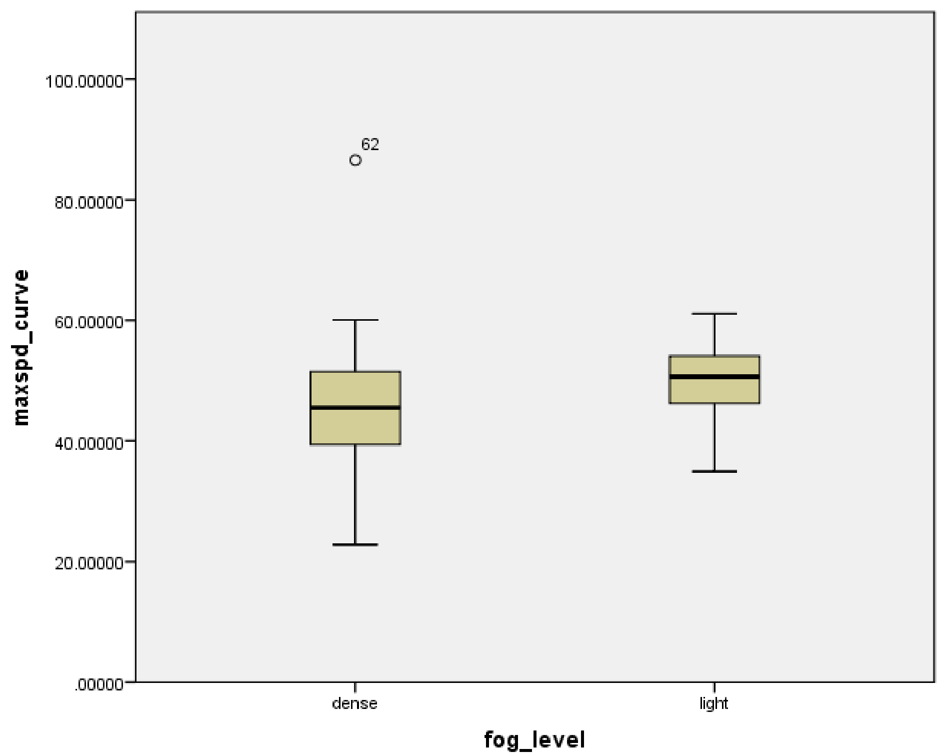

Figure 3-15 Box Plot for Maximum Speed based on Fog Level

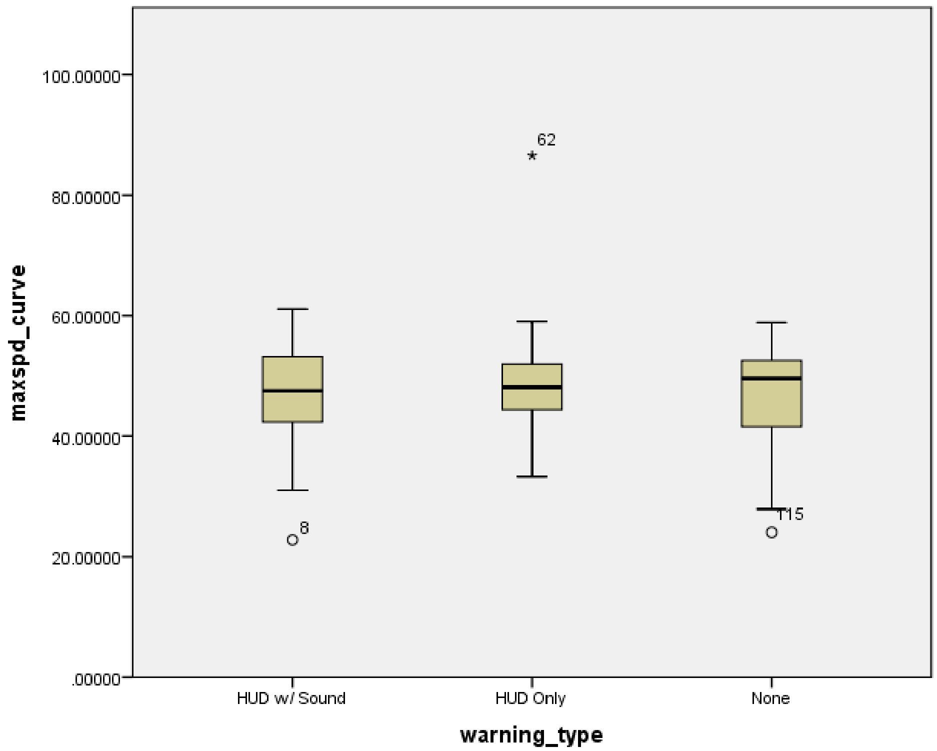

Figure 3-16 Box Plot for Maximum Speed based on Warning Type

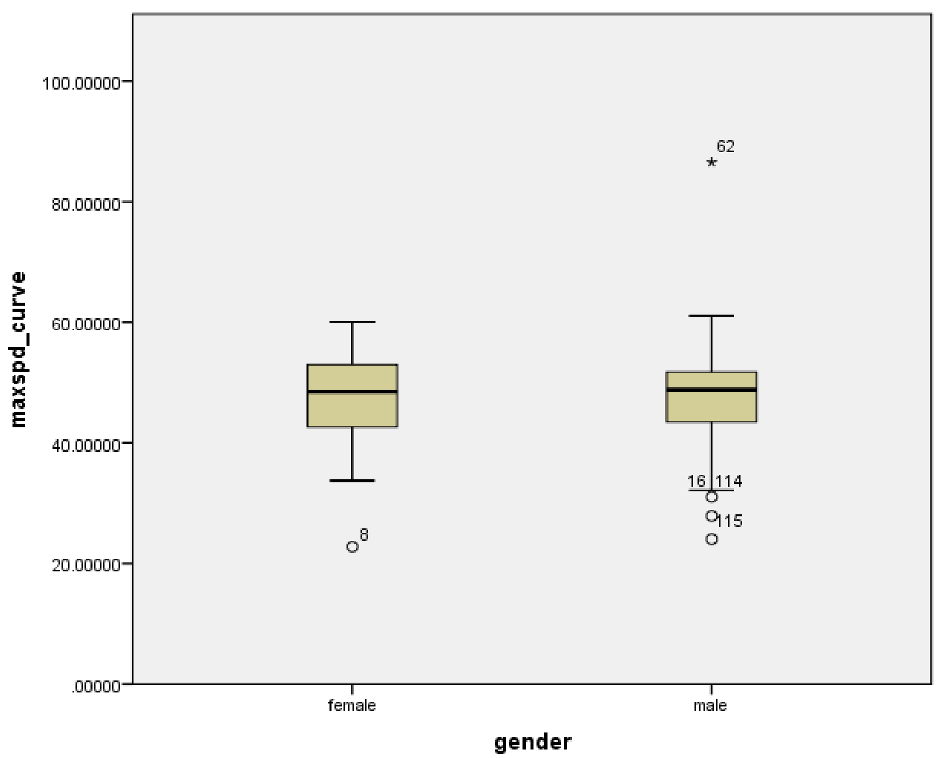

Figure 3-17 Box Plot for Maximum Speed based on Gender

3.7 Analysis of HUD based on questionnaire

Based on our post-experiment questionnaires, we also performed an independent t-test to analyze the participants' attitude towards different warning message. We have questions for the car following and curve sections in the scenarios, which are:

"Under the connected vehicle environment, how helpful were the "Curve Ahead" warnings in the Head-up Display? "

"Under the connected vehicle environment, how helpful were the "Keep Your Distance" warnings in the Head-up Display? "

3.7.1 Analysis of Gender

Based on the following tables (Table 3-9 and Table 3-10), we could conclude that there are significant differences in the results between male and female drivers. Female drivers have more positive attitude towards the HUD warning information at curve.

Table 3-9 Ratings for Curve Warning based on Gender

Question	GENDER	N	Mean	Std. Deviation	Std. Error Mean
Helpful.CurveAhead	Male	25	4.04	0.889	0.178
	Female	23	4.61	0.583	0.122

Table 3-10 T-test based on Gender

Question	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Helpful.CurveAhead	-2.596	46	.013	-.569	.219	-1.010	-.128

3.7.2 Analysis of Age

From the tables below (Table 3-11), there is no significant difference between different age groups. However, elderly people have more positive attitude towards the warning system. One of the possible reasons is that elder drivers are more sensitive to fog during driving. Therefore, the warning systems could compensate more for the reduction of the driving capability under fog conditions.

Table 3-11 Ratings for Curve Warning based on Age

AGE	N	Mean	Std. Deviation	Std. Error Mean
Young	18	4.17	0.857	0.202
Working-age	18	4.28	0.895	0.211
Elder	12	4.58	.515	.149
AGE	N	Mean	Std. Deviation	Std. Error Mean
Young	18	4.17	0.857	0.202
Working-age	18	4.28	0.895	0.211
Elder	12	4.58	.515	.149

CHAPTER 4: CONCLUSIONS

Extreme weather conditions could affect significantly negatively normal driving. Reduced visibility condition is one of the common adverse weather conditions that would weaken drivers' ability of controlling the vehicle and drivers' perception of the road alignment. Especially, when the visibility is extremely low, drivers might not be able to see the traffic signs and the pavement markings. It might lead to the failure of lane control or other dangerous situations, which could cause serious traffic safety problems.

This thesis mainly discussed the contributing factors for the reduced visibility single vehicle crashes at the first part. The results show that distracted driving, wet road surface and dark without streetlights are the main contributing factors for severe fog-related single-vehicle crashes. In the second part, a Heads-up Display (HUD) based curve-warning system driven by V2V/V2I communication was tested using a driving simulator. The results show that female drivers are more likely to deviate from the lane under fog conditions. In addition, lane departure is more likely to happen under dense fog conditions. Moreover, our results show the curve-warning system with warning sound is quite efficient. In addition, this system is more acceptable to female and elder drivers. It is helpful to have a curve warning system under low visibility conditions.

Based on our results, some safety driving strategies and tips could be given to drivers, automobile manufacturers, and highway management & operation departments. It is crucial to be aware of the potential risk of driving under fog for drivers. And it is better to avoid driving under dense fog if possible. It could bring considerable safety benefits if they could drive more careful under low visibility conditions.

For automobile manufacturers, equipping a driving vision enhancement system (e.g. HUD, Augmented Reality (AR)) would be a good idea. Connected vehicle technology such as I2V could reduce the crash risk under low visibility conditions. For highway management and operation departments, providing connected vehicle technology such I2V could be a good direction for future infrastructure plans. It would also be advisable to provide vision enhancement to the infrastructure such as reflective road surface marking along the roadway, and luminous tape at curve locations to help drivers under low visibility conditions especially during nighttime.

APPENDIX A: MATERIALS FOR DRIVING SIMULATOR EXPERIMENT

Evaluating Managed Lane and Fog Systems Conditions Using Driving Simulation

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February 2017

1. PROTOCOL TITLE

Evaluating Managed Lane and Fog Systems Conditions Using Driving Simulation

2. PRINCIPAL INVESTIGATOR

Mohamed Abdel-Aty, Ph.D., P.E.

3. OBJECTIVE

There are two main objectives for this driving simulator experiment. The first is to determine driver behavior in varying fog conditions and explore the impacts of different fog warning systems on driver behavior. The second is to study driver behavior while driving from general purpose lane to managed lane. To do this, participants will run through different scenarios on a NADS MiniSim driving simulator provided for the research. Variables of interest for the experiment will also be collected from the participants, which will be observed with the results of the simulations to see if there is any correlation with these variables and the results from the scenarios. These variables will be collected anonymously and include the participant's age, gender, driving experience and frequency, highest education level, accomplished income level, or zip code, and whether they have been in an accident in the last 3 years. Questions will also be given to the participants in written form before, during, and after the experiment in order to collect additional information that may provide an impact in the results. Feedback will also be collected from the participants at the end of the simulation which will be used to make improvements to future simulation research projects. Further, a questionnaire survey will be also conducted to investigate users' preference on HUD design under fog condition.

Source: Mini Sim Driving Simulator (http://sonify.psych.gatech.edu/research/driving/index.html)

(4)

Questions asked prior to the simulation testing involve determining the participants driving history and experience, as well as familiarity in fog conditions and managed lane, as well as variable collection. These questions also allow us to get a better understanding of individuals driving habits and whether they will experience any sort of motion sickness during the testing. At the end of the entire simulation test, subjects will again be asked if they are feeling well enough to leave and feedback will be collected from the participant on what they thought of the simulation experiment. By using this feedback, we have the opportunity to improve future simulation studies. (Samples of these questions that will be asked can be found on the attached questionnaire.)

Once the simulations have been completed and the required data has been collected, we will then analyze the results to see how people react in fog and warning systems, as well as managed lane. From our research, we hope to find ways to improve the safety of our roadways by determining potential benefits from the tested environments.

4. BACKGROUND

Studying driving behavior in a real-world scenario can be extremely challenging and dangerous, especially when these situations involve adverse conditions, such as fog. Due to unpredictability, it is hard to create fixed or constant environmental factors along the physical roadways. Interference from other drivers can also complicate data and pose potential safety hazards when trying to conduct studies with volunteers. Simulations allow us to test specific scenarios under user specific conditions, allowing for more control over the environment and consistency between each participants tests. Using simulation software also allows a cheaper alternative to testing driving behaviors compared to bigger more advanced systems such as Virginia Tech's "Smart Road." Although the simulation scenario is not as realistic as a 'real world' setting, we can validate the data in many different ways, one of which, stated by Dr. Kathy Broughton, Dr. Fred Switzer, and Dr. Dan Scott in their "Car Following Decisions" paper, would be to simply compare it to results from 'real world' studies and see if the trends are comparable (1-2). This is an absolute possibility for this research, as a sensor will be placed at the location the fog scenarios are based on. Ultimately it was determined from the investigation that driving simulation studies were much safer and more economic than a real world setting.

Currently, there have been many research and study topics involving the analysis of driver behavior in fog conditions using driving simulation. However, many focus on simply how varying fog levels compare to collision, driving behavior, or sight distance. For this study, we will be focusing on whether the presence of a warning system effects an individual's driving behavior in fog conditions, and in what way it impacts this behavior. Validation in this regard will be simple as well thanks in part to the previous fog simulation studies. Again, many of these past studies have focused on purely driving behavior, and many of which drew similar conclusions and results based on their studies. It was found that there is much consistency in driving behavior (acceleration or deceleration in fog, braking, speed, etc.) in fog conditions (3), meaning that it could be possible to validate the results based on other simulation findings if the data is consistent.

Besides, the research team will investigate the effectiveness of warning strategies on low visibility conditions utilizing driving simulator. Various low visibility warning systems will be tested for different combinations of scenarios to assistant drivers' decisions or avoid certain type of crashes. Based on the tested results of driver behaviors, we can examine which warning types are the most safety effective among the various types such as messages (e.g., sentence, pictogram, etc.), sound, and vibration. It is expected that appropriate warning systems can be suggested to enhance safety in fog condition based on our driving simulator experiment.

Besides the fog conditions, the managed lane is also studied in our experiment. Managed Lanes are designated lanes where the flow of traffic is managed by limiting vehicle eligibility, restricting facility access, or variable price tolls. The managed lanes have emerged as an effective dynamic traffic management strategy. In recent years, several major cities in the United States have introduced managed lane systems such as ETLs (Express Toll Lanes), HOT (High-Occupancy Toll) lanes, or HOV (High Occupancy Vehicle) lanes.

In order to efficiently and safely operate the managed lane system, it is necessary to determine the safe length and location of weave access zones nearby on- or off- ramps. Although many managed lanes have been built and various safe length has been recommended (4-5), most of studies were based on microsimulation. In our driving simulator experiment, we aim to test drivers' lane changing behavior and investigate whether the length is sufficient for the drivers to merge into or out from the managed lane. Drivers require enough time (distance) to decide to use (leave) the managed lane. This decision-making process should take more time compared to general lane changing, merging or diverging, since they need to reasonably think if they have a willingness to pay the current toll rate in improve mobility (e.g., reduced travel time). Thus, there are two major cases we need to consider: fist, a distance from an upstream managed lane exit to the next downstream off-ramp; second, a minimum distance from an upstream on-ramp to the next downstream managed lane entrance.

5. SETTING OF RESEARCH

The simulation study will be conducted at the University of Central Florida, in one of our available offices in Engineering building II. The office itself is large enough to accommodate the testing equipment and personnel, and is easily accessible by the research assistants. Since the research location is conducted within the UCF engineering building, many accommodations and equipment are readily available in case of any issue. Restrooms and water fountains are accessible to participants and personnel, and first-aid kits, fire extinguishers, and so on are also ready to use.

6. RESOURCES AVAILABLE TO CONDUCT HUMAN RESEARCH

Since we plan on recruiting many of the participants for this study through friends, family, and the University itself, many recruitment options are available to us. Friends, family, and even possibly campus faculty can be easily contacted and requested for participation either in person or by other means of communication. However, recruiting students for the study will require a bit more work to accomplish. The current plan is to advertise the study by word of mouth in classrooms, clubs, and around campus to recruit potential volunteers for the short study.

Overall, the simulation study should only take around one hour to complete, making time commitment not a huge problem. This hour block includes pre-simulation procedures, such as going over the disclaimer and allowing the participant time to practice becoming more acquainted with the simulator. Three questionnaires will be given to the participants throughout the study. One is before driving the simulator, and two are after the experiment. Following these preliminary procedures, each subject will then run through 7 scenarios chosen at a random order from a pool of created scenarios. The scenarios chosen will vary between the managed lane and fog related scenarios. Assuming each scenario lasts 4-6 minutes, there should be plenty of time to familiarize the participant, run the tests, and even allow some time in between tests for the participant to rest if he or she needs it.

A majority of the research group involved in the research have a few years of transportation safety research experience, a few already obtained PhD’s in the field. We are also working with other universities in the country. These include the University of Massachusetts Amherst and the University of Puerto Rico who have current experience in simulation research. The other universities will have no access to the data that we will collect. The only collaboration we will have and have had with these universities is guidance with simulation research, since they have more experience in the field. Furthermore, we will only share our results and findings with them in order to expand this research further. They are not involved in the data or experiments.

As previously stated, the simulation will be conducted in a private office inside Engineering Building II on UCF campus. Access to the room is approved, and only a select few research staff have access to the room and simulator. Amenities, such as water fountains and restrooms are readily available, as well as seating if someone needed to rest. While the simulation is being conducted, participants will be with at least one staff member at all times to monitor them and walk them through the procedure.

7. STUDY DESIGN

7a) Recruitment

For this experiment, a maximum of 54 subjects will be needed to run the simulation and be tested. The subjects will ideally range from ages 18 to late 60's, and each will be a Florida resident. Since most of the variables of interested in this study are based on the participants' demographics, a nice even distribution will need to be met to assure unbiased results. To meet this, we will recruit a variety of subjects with varying age, gender, education, ethnicities, and backgrounds. Participants will run the simulations through voluntary means, and will be recruited through UCF clubs and classes, friends or relatives, and possibly other local students who are interested in the research. No matter how they are recruited, each participant is expected to run through the scenarios presented in the MiniSim as if they were, or as close as possible to, driving in a real life scenario.

Participants will be recruited during the months of February, March, and possibly April. The family and friends of the researchers be recruited by word of mouth or by e-mail. Likewise, faculty and staff will also be recruited by word of mouth or by e-mail. A description will be given to explain the basis of the research and will be sent out through these e-mails.

Identifying potential participants will not be a difficult task for this research because the only requirements are as follows: The participant must be in the age range of 18 to late 60's, must have a driver's license, and must not have a history of motion sickness. Being in a college environment, it should be possible to find many potential participants. As stated previously, 54 subjects will be needed to complete this research study.

7b) Compensation

Since this experiment will only last one hour in total and it is being ran strictly through voluntary participants, no compensation is planned on being offered.

7c) Inclusion and Exclusion Criteria

In order to be eligible for this research experiment, participants must fit within a predefined demographic determined by the research group. The demographic of interest includes both male and female Florida residents ages 18 to late 60's. The participants must have a valid driver's license and have no history of extreme motion sickness or other medical conditions that can be caused by disorientation such as seizures or strokes. Subjects must also be physically capable of concentrating at a computer screen for at least half one hour without having any complications.

Each person who partakes in the simulation testing will have general information about themselves questioned and or recorded. These include age, gender, ethnicity, driving experience and history, approximate income, and a few other general variables that could prove to be significant in the final analysis. Assuming the participant meets the required criteria and performs the simulation, additional variables and information will be gathered from the participant including data from their scenario performance and info on the driver's reaction based on their answers to the post simulation questions. The data that we are most interested in for this experiment is primarily the driving behavior, including speed, acceleration or deceleration rates, brake usage, lane changing, and vehicle distancing just to name a few. With the addition of the questionnaire we can also gain information in regards to how the participant reacted to the given scenarios. Information such as; were the sign(s) encountered easy to read or understand, how confusing the scenario was, or even how they reacted to a specific event can provide valuable research information in terms of driver reactions.

Again, 54 participants are expected to be needed for the study; the results from each subject are expected to be used. The only situation where data results will be ignored or not used is if a situation occurs that results in an early withdraw of the participant or an error occurred during the simulation. Since the experiment requires the participants to have a driver license and must be at least 18 years or older, no children or teenagers will be considered for this research.

7d) Study Endpoints

N/A

7e) Study Timelines

The participants are expected to come to do the experiment twice, at the very most, 30 minutes for each time. This includes the explanation of what will be needed of them during the study, the scenarios the subject will be tested on, and breaks in between scenarios, as needed. It is estimated that testing will take 3 to 4 months. The primary analyses should be completed by May 2017.

7f) Procedure

The overall procedure for running the simulation should not take more than one hour for each participant, and each run will aim to be as consistent as possible. Before the simulation is started, each participant will be given a consent form that goes over what is expected of them and any possible health advisories. This consent form must be read and sign by any participant before any testing can begin so each participant knows what to expect. Once this is done, the subject will be given preliminary questions in written form, including questions on the variables of interest (age, gender, etc.), and then will be given a test simulation to get them more acquainted and comfortable with the hardware. This portion of the procedure should take approximately 10 minutes where ideally the participant gets 5 minutes of test driving in the simulator.

Following this initial practice, the participant will be given short rest if needed and then the actual study scenarios will be provided. Prior to starting the group of scenarios, the participant will be reminded of what their task is in the simulation. Between each scenario group, the participant will also be given the option to take a rest if they are feeling motion sick or ill, and if they are unable to continue the test will be concluded. After driving the simulator, the participant will be questioned in regards to the scenarios they just ran and their preference of head-up display design for fog conditions. Attached is a copy of each questionnaire used.

Since this simulation study is looking at both fog warning systems and managed lane conditions, the scenarios that the subjects will run involve completely different conditions. To keep things more in order and consistent, the groups of scenarios will each be based on one study. For the first group, both a freeway and arterial road will be generated and along them will contain a random fog and sign condition. In order to create a valid experiment, a pool of many different scenarios with varying conditions will be created, but only a few will be used randomly on each participant. The same applies for the managed lane as multiple conditions could be present and needs to be tested.

Ideally seven random scenarios will be chosen for both the fog and managed lane simulations, each taking around 4 to 6 minutes. After all this simulation data is collected, analysis will begin to determine correlation between driving conditions and participant data.

There are four recording devices that are used by this simulator. One device is pointed directly at the participant’s feet and will record only their feet. One is directed towards their face and another towards their hands. The last recording device will be located behind the participant, recording the monitors and where they direct the simulated vehicle. It is necessary to note that the researchers will be the only people that will access these videos and they will be deleted immediately after the necessary data is collected. The videos will be stored in a locked, safe place. The data collected from these videos include, but are not limited to, eye movements, gas and brake pedal usage, and head movements. There is very minimal risk when using the MiniSim. The only risk the subjects have in using the simulator is motion sickness. In this case, the subject would be provided water and a cool place to sit. The motion sickness will be monitored by the research assistants who will watch for signs of uneasiness.

Data collected during the experiment range from how the subject uses there pedals to how often they switch lanes to swerving. Data will also be collected using the questionnaires. This data includes age, gender, years of driving experience, years of driving experience in Florida, how often a person uses toll roads or roads susceptible to fog, occupation, range of income, highest level of education, how realistic the person thought the scenarios were, etc.

For the fog related scenarios, the participant will drive through arterial lanes with varying fog and warning system conditions. These scenarios will be based in Paynes Prairie, Gainesville;

a location that has seen severe crashes in the past due to visibility issues. By basing our study on this location, we gain the added benefit of using data collected from the actual site to compare and validate the simulator results. As previously stated, multiple scenarios will be made for different situations including fog density and warning system presence. Normally each scenario will begin under clear or slight fog conditions and as the driver proceeds down the courses, the set conditions will begin to change. From this pool of scenarios, 3 scenarios will be randomly selected for each participant to run.

The managed lane simulation will be based on the managed lane on Interstate Road 95 in Miami, Florida. In order to merge into managed lane, drivers need to change multiple lanes. Thus, it could be extremely dangerous if the length for drivers to change lanes from ramp to managed lane or from managed lane to ramp is not enough. There are two major cases we need to consider: first, a distance from an upstream managed lane exit to the next downstream off-ramp; second, a minimum distance from an upstream on-ramp to the next downstream managed lane entry. Drivers require sufficient time to decide to use (or leave) the managed lane. This decision making process takes more time compared to general lane changing, merging or diverging, as they need to reasonably think if they have a willingness to pay the current toll rate to improve mobility (e.g., reduced travel time).

7g) Data Specimen Management

N/A

7h) Provisions to Monitor

N/A

7i) Withdrawal

If participants show continuous or extreme signs of motion sickness, he or she will be withdrawn from the simulation test. Once withdrawn, the participant will be given a place to rest and water until they feel well enough to leave.

In a situation where a participant was withdrawn from a test, the data collected will most likely be invalidated and will not be used. However, if the participant completes a specific scenario prior to the issues causing the withdrawal to occur, then the data for those scenarios might still be usable. Also since the participant withdrew from the experiment early, whatever form of compensation offered will be changed based on how long the testing process took.

8. RISKS

The main risk that is encountered while driving in the simulation is motion sickness, or any other form of motion related ailments. If a subject begins to feel any uneasiness or needs a break, they will be free to do so. Once out of the simulator, the sickness should subside momentarily. At the end of the test, subject will also be questioned to give them time to relax and will be offered a place to rest if they need some time before they leave. Also, were any serious problem occur, a researcher will be with the subject at all times so participants should never be along for long periods of time.

9. POTENTIAL BENEFITS

Overall there is no real direct benefit towards participants in this study other than compensation or learning something about the transportation engineering field and simulation research. The participant will also be contributing to research for safer and more efficient roadways.

10. PROVISIONS TO PROTECT PRIVACY OF PARTICIPANT

The simulation tests will be conducted behind closed doors with only the research assistants and participant present. The data collected from the subject will be completely anonymous, where no information collected from the participant will be related to a name or identity. If subjects are not comfortable answering a question, such as income or crash history, a value range will be provided to choose from or the participant has the right to not answer. The data collected will be strictly used for academic purposes and will only be accessible to those involved in the research group.

11. PROVISIONS TO MAINTAIN CONFIDENTIALITY

In order to maintain confidentiality of the data, as well as the participants, all data collected will be kept secure where only research staff will be able to access and look at it. Subject names will also not be used, recorded, or related to the data collected from the participants in order to assist in creating anonymous data. The data is also going to be restricted to limited use, not only by who can access it but also where it can be accessed. The data will be stored for at least five years after the research study has been completed, per UCF IRB Policies and Procedures.

12. MEDICAL CARE AND COMPENSATION FOR INJURY

N/A

13. COSTS TO PARTICIPANTS

Participants may incur a cost for parking, if this occurs, they will be reimbursed.

14. CONSENT PROCESS

All consent will be taken care of at the very start of the study, prior to any simulation testing on the participant. Each participant will be given an informed consent form that they are to go over and sign before any testing can begin. While the participant does this, the available staff at the time will go over the form with them, ideally in the first 10 minutes, covering the most important parts of the document and check with the participant to ensure that they understand what is being discussed. This means that before any testing has begun, the participant will have been given a verbal form of consent for both what is expected of the simulation as well as understanding. The potential participants will be asked if they have had a seizure or if they have a history of seizures. They will be excluded from partaking in the study if they answer “yes” to this question. Also, since the participant if free to withdraw from the simulation at any time, a person’s willingness to continue shows adequate ongoing consent.

Since all the participants expected to take part in this experiment are Florida residents, we can assume that practically all of the participants will have English as a primary language or at least have a firm grasp the language. This will be the only language spoken during the study and we will not be able to recruit participants that do not know English.

15. CONSENT DOCUMENTATION

A written consent form will be provided prior to any testing, and will be gone over by the tester to ensure the participant understands everything. Before the simulation is started, each participant will be given a consent form that goes over what is expected of them and any possible health advisories. This consent form must be read and sign by any participant before any testing can begin so each participant knows what to expect. The assistant conducting the research will also be available to answer any questions the participant may have and go over the consent form with them. Once this is done, the participant will be given preliminary questions, including questions on the variables of interest (age, gender, etc.).

16. VULNERABLE POPULATIONS

N/A

17. DRUGS AND DEVICES

N/A

18. MULTI-SITE HUMAN RESEARCH

N/A

19. SHARING RESULTS WITH PARTICIPANTS

N/A

SUMMARY

Through observation of the results of these simulation scenarios, we hope to use the findings to determine more efficient ways to use warning systems for adverse weather conditions, as well as improve efficiencies at managed lane. The work done and data collected also provides a base for other research projects and studies to read the data or do further testing on the results. As far as fog research, these studies can include closer analysis on the type of warning systems used. These managed lane studies will comprise of determining safe length of location of weave access zones nearby on- or off- ramps. Again, one of the biggest issues with simulation studies is validation of the simulation environment to accurately reflect real world data. Luckily, this will not be too big of an issue due to having access to traffic data collected from the sites of interest.

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Evaluating Managed Lane and Fog Systems Conditions Using Driving Simulation

Informed Consent

Principal Investigator:	Mohamed Abdel-Aty, PhD. P.E.
Co-Investigator(s):	Yina Wu, PhD Candidate Qing Cai, PhD Candidate
Sub-Investigator(s):	Jaeyoung Lee, PhD Juneyoung Park, PhD
Sponsor:	Florida Department of Transportation National Center for Transportation Systems Productivity and Management UTC SAFER-SIM UTC
Investigational Site(s):	University of Central Florida, Department of Civil, Environmental, and Construction Engineering

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 54 people from around the Orlando area as well as faculty, staff, and students at UCF. You have been asked to take part in this research study because you are within the age range of 18-65 and have driver's license. You must be 18 years of age or older to be included in the research study.

The people conducting this research are Yina Wu and Qing Cai of UCF Department of Civil, Environmental, and Construction Engineering. Jaeyoung Lee, Juneyoung Park, and will also be helping with this research. The researchers are collaborating with Dr. Michael Knodler and Dr. Donald Fisher from the University of Massachusetts Amherst, as well as graduate students from the University of Puerto Rico in Mayaguez. Because the researchers are graduate students, they are being guided by Mohamed Abdel-Aty, PhD P.E., a UCF faculty advisor in the department of Civil, Environmental, and Construction Engineering.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of this study is to evaluate driver behavior (1) in fog conditions along a roadway with or without fog systems presence and (2) on managed lanes and general purpose lanes under different operating conditions.

What you will be asked to do in the study: The laboratory assistant, with whom you will interact, will give you a questionnaire to fill out before and after the experiment has been completed. This questionnaire will be kept confidential. You do not have to answer every question or complete every task. You will not lose any benefits if you skip questions or tasks. The laboratory assistant will then have you sit in the driver's seat of the simulator, which contains a steering wheel, gas and brake pedals, buttons that will be explained, three monitors that display the simulation world you will drive in, and another small monitor that displays the car's dashboard information. Before starting the actual testing scenarios, the laboratory assistant will execute a practice simulation, which involves a simple roadway and intersection. This practice scenario can be used to better acquaint you with the displays and how the vehicle operates.

Once you feel comfortable enough with the simulator, you will have a short break if needed and then continue on to the experiment. The experiment will consist of seven different and random scenarios that will last about 3-6 minutes each. You will finish four scenarios during your first visit, and finish three scenarios during the second visit. You will also have a 5-minute break in between each scenario if needed. Each visit should last a maximum of 30 minutes.

Location: As noted previously, the study will be done using a driving simulator. The simulator will be located on the main campus of the University of Central Florida. It is in the Engineering 2 building, room 325A.

Time required: We expect that you will be in this research study twice for, at the very most, 30 minutes each time.

Audio or video taping: You will only be videotaped during this study. If you do not want to be videotaped, you will still be able to be in the study. Discuss this with the researcher or a research team member. If you are videotaped, the tape will be kept completely confidential in a locked, safe place. The tape will be erased or destroyed immediately after we process the data. There are four recording devices that are used by this simulator. One device is pointed directly at your feet and will record only your feet. One is directed towards your face and another towards your hands. The last recording device will be located behind you, recording the monitors and where you direct the simulated vehicle. It is necessary to note that the videos will be kept confidential and only the researchers will be the only people that will access these videos. The data collected from these videos include, but are not limited to, eye movements, gas and brake pedal usage, and head movements.

Funding for this study: This research study is being paid for by the Florida Department of Transportation, National Center for Transportation Systems Productivity and Management UTC, and SAFER-SIM UTC.

Risks: Side effects of VE (virtual environment) use may include stomach discomfort, headaches, sleepiness, dizziness and decreased balance. However, these risks are no greater than the sickness risks you may be exposed to if you were to visit an amusement park such as Disney Quest (Disney Quest is a VE based theme park), Disney World or Universal Studios parks and ride attractions such as roller coasters. You will be given 5-minute breaks during the exercise, if necessary, to lessen the chance that you will feel sick. If you experience any of the symptoms mentioned, please tell the researcher and remain seated until the symptoms disappear. Water will also be provided to you if needed. Please let the researcher know if you have had a seizure or have a history of seizures.

Benefits: The benefits of this experiment will include contributing to the safety of future roadway designs and help researchers better understand driving habits in various driving conditions. There is no actual compensation or other payment to you for taking part in this study.

Confidentiality: We will limit your personal data collected in this study to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt you, talk to Yina Wu, Graduate Student, Transportation Engineering Program, Department of Civil, Environmental, and Construction Engineering, by email at jessicawyn@knights.ucf.edu, Qing Cai, Graduate Student, Transportation Engineering Program, Department of Civil, Environmental, and Construction Engineering, by email at qingcai@knights.ucf.edu or Dr. Mohamed Abdel-Aty, Faculty Supervisor, Department of Civil, Environmental, and Construction Engineering, by email at m.aty@ucf.edu .

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

I acknowledge that I have read and agree to the above Terms and Conditions.

Print Name: ________________ Signature: _______________ Date:________________

SIMULATOR QUESTIONNAIRE
Before the Experiment

1. How old are you?
   ____

2. What is your ZIP code (9-digit, on your driver license)?

					--				

3. What is your highest level of education?
   a. Less than high school diploma
   b. High school diploma
   c. Associate bachelors' degree
   d. Bachelor's degree
   e. Advanced degree or professional degree

4. Are you a professional driver / Does your job involve driving?
   a. Yes
   b. No

5. How long have you been driving a car?
   ____

6. How many years have you been driving in Florida?
   ____

7. Where did you learn how to drive?
   a. In Florida
   b. Outside Florida, but in United States
   c. Outside United States

8. What vehicle do you usually drive?
   a. Passenger Car
   b. Light Truck or Van
   c. Motorcycle

d. Recreational Vehicle (RV)
e. Other. If so, what is the vehicle type: ____________

9. How often do you typically drive?
   a. 1-5 trips per week
   b. 1-2 trips per day
   c. 3-5 trips per day
   d. 5+ trips per day

   If never, please explain:

10. Have you ever used a high-occupancy vehicle lane (HOV), a high-occupancy toll lane (HOT), or an express lane before?
    a. Yes
    b. Don’t remember
    c. No

11. Have you ever driven in any fog conditions in the past year?
    a. Yes
    b. No

12. Have you ever driven a car with Head-up display (HUD)?
    a. Yes
    b. No

13. Have you been involved in any vehicular crash in the last 5 years?
    a. Yes
    b. No

    If so, what was the crash type (e.g. sideswipe, rear-end, head-on, etc.)?

How many cars were involved?

Where did the crash occur (e.g. intersection, highway, toll plaza, etc.)?

Did you receive a citation when you were involved in the crash?

SIMULATOR QUESTIONNAIRE

After the Experiment

1. How do you feel during the experiment?

1	2	3	4	5
Very bad	Bad	Neither good nor bad	Good	Very good

2. Do you think the scenarios were logical and realistic to an actual life situation?

1	2	3	4	5
Very bad	Bad	Neither good nor bad	Good	Very good

3. Do you think the weaving length of the managed lane scenarios is enough for you to cross the four general purpose lanes?

1	2	3	4	5
Not at all enough	Not very enough	Somewhat enough	Enough	Very enough

4. Did you feel comfortable when you continuously change 3 lanes in the managed lane scenarios?

1	2	3	4	5
Not at all comfortable	Not very comfortable	Somewhat comfortable	Comfortable	Very comfortable

5. Under the connected vehicle environment, how helpful were the “Fog Ahead” and “Keep Your Distance” warnings in the Head-up Display?

1	2	3	4	5
Not at all helpful	Not very helpful	Somewhat helpful	Helpful	Very helpful

6. Under the connected vehicle environment, how helpful was the “Curve Ahead” warning in the Head-up Display?

1	2	3	4	5
Not at all helpful	Not very helpful	Somewhat helpful	Helpful	Very helpful

7. Under the connected vehicle environment, how helpful was the “Slow Vehicle Ahead” warning in the Head-up Display?

1	2	3	4	5
Not at all helpful	Not very helpful	Somewhat helpful	Helpful	Very helpful

8. Under the connected vehicle environment, how helpful was the warning sounds with the Head-up Display?

1	2	3	4	5
Not at all helpful	Not very helpful	Somewhat helpful	Helpful	Very helpful

9. Do you have any suggestions or feedback on how to improve the simulation or have any complaints in regard to the scenarios you ran?

APPENDIX B: APPROVAL OF HUMAN RESEARCH FOR DRIVING SIMULATOR

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Mohamed A. Abdel-Aty** and Co-PIs: **JaeYoung Lee, Juneyoung Park**

Date: **March 08, 2017**

Dear Researcher:

On 03/08/2017 the IRB approved the following human participant research until 03/07/2018 inclusive:

Type of Review:	IRB Continuing Review Application Form Expedited Review
Project Title:	Evaluating Toll Plazas and Visibility Conditions Using Driving Simulation
Investigator:	Mohamed A. Abdel-Aty
IRB Number:	SBE-15-11026
Funding Agency:	Florida Department of Transportation(FLDOT), Georgia Institute of Technology, University of Iowa
Grant Title:	Evaluating Toll Plazas and Visibility Conditions Using Driving Simulation
Research ID:	1650-8026, 1620-7100

The scientific merit of the research was considered during the IRB review. **NOTE: Because this study was not approved before the IRB expiration date, there was a lapse in IRB approval from 3/7/2017 to the new approval date above.** The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 03/07/2018, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Gillian Amy Mary Morien on 03/08/2017 12:41:59 PM EST

IRB Coordinator

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